MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY

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MEETING OF 1943 OCTOBER 8

Professor E. A. Milne, President, in the Chair

The election by the Council of the following Fellows was duly confirmed:—

Dana Kavanagh Bailey, B.S., M.A., 3902 Spuyten Duyvil Parkway, New York City, U.S.A.;

Howard Laurence Kelly, A.R.I.B.A., 44 Gilda Court, Watford Way, London, N.W. 7; and

Gunnar Randers, Kingston House South, London, S.W. 7.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Frederick Walter Bowley, Master Mariner, 50 Clifden Road, Twickenham, Middlesex (proposed by W. H. Coombs);

Gordon Ellis, Blodfryn, Bryn Pydew, Llandudno Junction, N. Wales (proposed by J. A. Lloyd);

Wilfred Hutchings, The Royal School, Armagh, N. Ireland (proposed by E. M. Lindsay);

John Leslie Rudd, Roan, Abinger Hammer, near Dorking, Surrey (proposed by H. Spencer Jones); and

Arthur William Wilkinson, 127 Malham Road, Forest Hill, London, S.E. 23 (proposed by F. J. Hargreaves).

Thirty-eight presents were announced as having been received since the last ordinary meeting.

At a Council meeting, held 1943 December 10, the following were elected Fellows of the Society:—

William Edward Beart, c/o B.B.C., Tatsfield, Westerham, Kent;

Miss Kathleen Maud Johnston, Acton Reynold Girls' School, near Shrewsbury;

Dennis Edwin Piper, 8 Kent Gardens, Ealing, London, W. 5;

Charles John Veale, 111 Holden Road, London, N. 12; and

Achill Wheatley, B.Econ., 42 Farm Avenue, London, N.W. 2.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Dudley Perrin Bayley, B.Sc., F.I.C., A.R.S.M., Oban, Greenbank Road, Latchford Without, Warrington, Lancashire (proposed by F. J. Sellers);

Herbert John Fenner Burroughs, 93 Middle Crescent, Iscor Township, Pretoria, Transvaal, S. Africa (proposed by H. E. Houghton); and

John Gibson Kerr, Director, Observatory, Calton Hill, Edinburgh (proposed by C. F. O. Smith).

SELECTIVE ABSORPTION NEAR THE NORTH POLE AND THE SPECTRUM-COLOUR RELATION

Frederick H. Seares

(Received 1943 October 14)

Summary

Discussion of spectral types and colour indices (Mount Wilson *Polar Catalogue*) for about 1000 stars north of +80° declination gives (1) the magnitude error in C, (2) a revised spectrum-colour relation, (3) the mean colour excess as a function of distance. The magnitude error, which affects stars brighter than *Pv m* 9·2 of types earlier than Go, accounts for the contradictions in the selective absorption and in the colour of Ao stars found by E. G. Martin. For Ao the absorption-free value is $C = -0{\cdot}15$ mag. The obscuring cloud, which apparently extends to about 450 parsecs, produces a maximum colour excess of 0·27 mag. (international system).

In *Monthly Notices*, **102**, 261, 1942, Mr. E. G. Martin is led to the conclusion that the selective space absorption of starlight in the region of the North Pole is considerably less than the amount found by Stebbins, Huffer, and Whitford * and by myself.† He also questions the value $-0{\cdot}15$ mag. for the mean colour index of Ao stars in "unobscured" regions, obtained by Ross and Zug from comparison stars for Eros and confirmed by Mount Wilson measures of various kinds.‡

Martin's argument is based largely on colour indices of early-type stars taken from the Mount Wilson *Polar Catalogue* §, apparently without consideration of the note appended to the Introduction (p. 49). This note, which was added to the final proofs, points out that, even after allowing for space absorption, the colours of the brighter A and F stars are not independent of magnitude. Oversight of this circumstance accounts for the more serious of the contradictions found by Martin.

At first it was uncertain whether the magnitude error thus revealed was in the colour indices themselves or in the spectral types used for their intercomparison. Meanwhile, the error itself, the absorption, and several related questions have been investigated as fully as the present data permit, in three *Mount Wilson Contributions* by Miss Joyner and myself now in the hands of the *Astrophysical Journal*. Since these results may not be easily accessible in England for some time, the principal conclusions are summarized here.

Each polar star provides an equation of the form

$$C - \delta C - E - C_s = 0, \qquad (1)$$

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* *Mt. W. Contr.*, No. 650; *Ap. J.*, 94, 215, 1941.

† Mt. W. Annual Report, *Year Book Carnegie Inst. of Washington*, No. 38, 17, 1938–39.

‡ *Trans. I.A.U.*, 6, 215, 1938. Stebbins and Whitford, *Mt. W. Contr.*, No. 586, p. 14; *Ap. J.*, 87, 250, 1938. The second citation explains (and revises slightly) the value of C for Ao stars derived from photo-electric measurements which was quoted in *Trans. I.A.U.* The data used are not those mentioned by Martin, and the result does not depend on the ratio of total absorption to colour excess.

§ Seares, Ross, and Joyner, "Magnitudes and Colours of Stars North of +80°," *Carnegie Institution of Washington*, Publication 532, 1941.

where C is the *Catalogue* colour index, δC its error, E the colour excess, and C_s the colour index (absorption free) inferred from the spectral type. The values of δC cannot be found without solving at the same time for E and C_s. Three statistical relationships are thus involved whose regression lines are functions of magnitude, distance, and spectral type. With an abundance of data the solution is determinate, and the regressions can be evaluated by successive approximations.

A complication, in the beginning at least, is the possibility of a magnitude error in the spectral types, especially in those obtained from objective-prism spectrograms. Any such error combines with δC and must be allowed for later by intercomparing results from spectral series having different classification limits and including, if possible, types from slit spectrograms, as well as from objective-prism plates.

The spectral classifications used (which were all reduced to the HD system) comprised types from Harvard (HD 548), Upsala (Petersson, 847), Bergedorf (Schwassmann, 170), Yerkes (Keenan and Babcock, 52), Mount Wilson (Adams and others, 53), and a few by Parkhurst; altogether about 1700 values for roughly 1000 stars. Giants were segregated from main-sequence stars on the evidence of colour index and type. The designations thus made agree with Mount Wilson throughout (only 38 stars, however) and with Upsala for 84 per cent. of the 424 Upsala G–M stars. Distances for individual stars were calculated from apparent magnitude and the mean absolute magnitude for the type in question.

For the data used (the restriction is to be noted) magnitude errors in type are negligible, except for objective-prism results on stars close to the classification limit. The HD types for faint G–M stars are erratic and were usually omitted. The faint HD A–F stars, on the other hand, are consistent, but for most subtypes (not Ao, however) seem to have been classified a little too late. All these stars were retained and used with corrected types. A few Upsala types for tenth-magnitude stars were also slightly changed. On the whole, though, systematic classification errors proved less disturbing than had been expected.

TABLE I

Magnitude Error in Colour Indices *

Pv m	δC B–F	*Pv m*	δC	
			B	A, F
⩽6·0	+0·07	8·0	−0·05	−0·05
6·5	+0·06	8·5	−0·07	−0·06
7·0	+0·04	9·0	−0·06	−0·03
7·5	0·00	⩾9·2	−0·06	0·00

* δC to be subtracted from *Catalogue C*. For B-type stars fainter than *Pv m* 9·2 the correction doubtful.

The adopted results for δC, C_s, and E are in Tables I–III. The errors in C affect only stars having types earlier than Go and magnitudes brighter than 9·2 photovisual. The correction curve for B stars below this limit is uncertain, however, owing to the scarcity of such stars. The HD A2–F5 types for faint stars give a curve which agrees with that for the B–Ao stars shown in Table I. In other words, the latter curve, by accident, represents the combined influence of errors in C and in type for the HD A2–F5 stars.

The values of C_s from spectral data by different observers (after reduction to the HD system) agree well. The summary in Table II is the mean result for all the series, and some of the Eros stars as well. Altogether, 1850 spectral classifications and about 1100

values of C are involved. The ends of the curve are still weak, however, since there are only 28 classifications earlier than B9 and 36 of K5 and later.

The exact significance of these results for C_s should be noted. First, the zero points of the Polar Sequence standards, and hence of the *Polar Catalogue*, refer to the zenith; but the individual magnitudes and colour indices still include the differential atmospheric extinction caused by differences in stellar temperature. With the aid of effective wave-lengths for the international system, these quantities can now be calculated. Since all the observations used in deriving the Polar Sequence standards were reduced to the Mount Wilson colour system, the differential effects required are those affecting observations made from Mount Wilson at the altitude of the Pole. For *Pv m* the effect is negligible, but not for *Pg m* and C. To complete the reduction to the zenith, the Ao–gKo range in C_s must be increased from 1·21 to 1·27 mag. (C_s for A5 remains unchanged). For air mass zero the range becomes 1·32, and zero-point corrections of −0·295, −0·136, and −0·159 mag. must also be applied to *Pg m*, *Pv m*, and C_s respectively.

TABLE II

Colour Index C_s and HD Spectrum

HD	Main Seq.	HD	Main Seq.	Normal Giants
B5	−0·39	Go	+0·42	+0·60
Ao	−0·15	5	0·64	0·78
5	0·00	Ko	+0·89	1·06
Fo	+0·12	5	...	1·45
5	+0·26	Ma *	...	+1·47

* A numerical extension of the HD scale gives Ma = K7·7.

Second, the influence of stellar temperature on E has been neglected, necessarily, since the observational data do not permit its determination. The values of E which underlie Table II refer to a mean stellar temperature of, say, 8000° (about F5). High-temperature stars have therefore been undercorrected for absorption, those of low temperature overcorrected. The change in the Ao–gKo range in C_s, computed from the effective wave-lengths and a λ^{-1} absorption law, is an increase of 0·05. For the zenith the range, corrected for both residual extinction and absorption, thus becomes 1·32 mag.* Finally, the zero point for C_s (and for E also) is uncertain by 0·02 mag., as will appear in a moment.

The values of E from various groups of data—stars of different types, and types by different observers—also agree well. The general means for the whole polar cap north of 80° are listed first in Table III and followed by the results from the Bergedorf types for the small field of Selected Area 1, 3°·5 square. The colour excess increases at a nearly linear rate to a value of 0·27 mag. at about 450 parsecs (distance corrected for absorption) where the obscuring cloud apparently ends; at least there is no certain increase in E beyond this limit. The corresponding total *Pg* and *Pv* absorptions for a λ^{-1} law are 1·3 and 1·0 mag., respectively. Any non-selective absorption that may be present is, of course, additional to these amounts.

All these figures involve the tacit assumption that the absorption begins at zero distance; in other words, that the solar system is either at or a little within the boundary of the obscuring cloud. Some such assumption is necessary in order to fix the zero points for C_s and E, both of which initially must be regarded as unknown. The choice

* This value is 0·16 mag. less than that given in *Mt. W. Contr.*, No. 226, 1922. The earlier result is vitiated by the effect of absorption, which was then unknown.

TABLE III

Selective Space Absorption near North Pole

Distance (parsecs)		Colour Excess E (0·01 mag.)	No. Values	Distance (parsecs)		Colour Excess E (0·01 mag.)	No. Values
Appt.	Corr.			Appt.	Corr.		
34	33	1·9	115	869	542	25·7	18
62	58	3·4	72	944	589	28·6	27
82	76	4·4	131	1009	630	24·7	19
125	112	6·5	188	Selected Area 1—Bergedorf			
173	148	9·0	170				
223	188	9·7	184				
271	219	12·2	140	61	58	2·6	12
329	249	15·9	85	121	102	9·8	24
390	282	18·6	42	174	151	8·1	29
440	302	21·4	38	217	182	9·9	39
556	366	23·9	32	341	261	15·3	23
647	408	26·3	35	554	354	25·6	16
752	469	28·0	29	813	507	26·8	25
				1246	778	22·0	3

made gives the minimum possible values of C_s. The other extreme would be provided by supposing the absorption to begin at 33 parsecs (see Table III), the maximum distance to the cloud permitted by the observations, since the smooth run in the values of E is definite evidence of increasing colour from that point on. The zero-point difference corresponding to these two assumptions is the 0·02 mag. mentioned as an uncertainty in the values of C_s. Freed from absorption, the polar stars thus give for Ao stars a mean colour index whose limits are $-0·15$ and $-0·13$ mag. Since this result agrees closely with the value from Eros stars and other objects in apparently unobscured regions, it follows that the solar system, if actually within the polar cloud, cannot be far from its surface.

Subdivision of the polar cap into small fields confirms the general uniformity of absorption in the polar region suggested by the close agreement of the E's for S.A. 1 with the general means. Local deviations from the mean absorption are unexpectedly small for so large a range in galactic latitude ($18° - 38°$). The dispersion in E increases with the distance of the stars, as might be expected, but its maximum is only $\pm 0·04$ mag., or about one-seventh of the corresponding mean E.

Further discussion of the residuals for equation (1) shows that the local zero-point errors in the colour indices of the *Polar Catalogue* are small. For fields of 8–10 sq. deg. the mean error is $\pm 0·015$ mag. A result of general astrophysical interest is the dispersion in C for stars of the same spectral type (*i.e.* any of the usual sub-types with the added specification of giant or dwarf characteristics when pertinent). For types Ko and earlier the upper limit of the dispersion is $\pm 0·035$ mag., for K5–M stars about $\pm 0·1$ mag. The residuals also give useful information on the accidental errors of spectral classification.

Returning now to Martin's comments, we note from Table I that the colour indices of early-type stars of magnitude 8·5 are too small by 0·06 or 0·07 mag., while those of magnitude 6·0 are too large by an equal amount. The errors in C thus neutralize in large part the increase in C with increasing distance which would otherwise appear. Martin thus naturally finds little evidence of selective absorption when he uses the uncorrected colours for the A stars classified by Keenan and Babcock. The corrected colours, on

the other hand, give a positive result which (with allowance for difference in colour scale) is in good agreement with that obtained by Stebbins, Huffer, and Whitford * from their photo-electric measurements of these same stars.

The selection of these rather bright A stars was an unfortunate choice for a test. Had the F types of either Schwassmann or Petersson been used, both of which extend to the limit of the *Polar Catalogue* near *Pv m* 11·0, the absorption would have been unmistakable even without any correction of the colours. Since only stars brighter than *Pv m* 9·2 are affected, the errors have but little influence on the curves for *E* against distance. In fact, the increase in *E* with distance thus found is practically identical with that shown by the final values in Table III.

As for the value of *C* for "unobscured" Ao stars, the earlier evidence was already strong in spite of the uncertainty affecting the colour indices of some of the Eros stars. The foregoing result from the polar stars seems, however, to put the matter beyond any doubt. Moreover, other evidence is now available which further strengthens the conclusion, namely, that from the photo-electric measurements of Stebbins, Huffer, and Whitford of stars near the galactic poles * and of certain "unreddened" stars for which the results have been given in an article by Keenan and Babcock.†

Presumably the colours of all these stars are affected in some degree by the absorbing stratum that produces the peculiar distribution of the extragalactic nebulæ. There is, in fact, evidence of a small colour excess even at the galactic poles. Nevertheless, these objects are unobscured in the relative sense in which the term is used in speaking of the Eros stars, for example, or of any group of objects in the higher latitudes serving as standards for the measurement of the much larger colour excess in low latitudes. The selective action of the absorbing stratum is still so little known, however, that it is better to disregard it and continue for the present to regard stars known to be clear of the galactic dust clouds as "unobscured." Into this category, of course, fall the standards used by Stebbins and his associates for measurements of colour on the C_1 system.‡ These standard colour indices we denote here by the symbol C_{1s} and note that for

$$\text{MW Ao, } C_{1s} = -0{\cdot}10 \text{ mag.}; \quad \text{HD Ao, } C_{1s} = -0{\cdot}09 \text{ mag.} \tag{2}$$

The data for the galactic poles (NGP, SGP) and for the Keenan-Babcock list (KB) provide three other values of C_1 for Ao, and from the polar (rotation) stars (NP) we may obtain a fourth, giving five in all. To find the corresponding values of the colour of Ao stars on the international system (C), we require a relation between C and C_1, which may be found by combining results from the *Polar Catalogue* with the photo-electric colour indices of NP stars.§ Here it should be noted that the latter, as well as the colours for the NGP, SGP, and KB stars, are not referred to the normal zero point of the C_1 system defined by (2). Hence we designate them by C_1' and write

$$C_1 = C_1' + z, \tag{3}$$

where z is the zero-point correction for reduction to the normal system. From 52 early-type NP stars, grouped according to sub-types, we obtain

$$C = C_c - \delta C = (+1{\cdot}90 \pm 0{\cdot}18)C_1' - (0{\cdot}023 \pm 0{\cdot}023), \tag{4}$$

where C_c is the *Catalogue* colour, δC the magnitude error, and the appended quantities are mean errors.

For each of the four groups of stars we form the mean value of

$$\Delta C_1 = C_{1s} - C_1' = C_{1s} - C_1 + z. \tag{5}$$

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* *Mt. W. Contr.*, No. 650; *Ap. J.*, 94, 215, 1941. † *Ap. J.*, 93, 64, 1941.
‡ *Pub. Washburn Observatory*, 15, Pt. 5, 239, 1934; *Mt. W. Contr.*, No. 621; *Ap. J.*, 91, 20, 1940.
§ *Mt. W. Contr.*, No. 650; *Ap. J.*, 94, 215, 1941.

For stars well away from the Milky Way, differences in any small colour excess are negligible, and as a condition for determining z we write $C_{1s} = C_1$. For the NP stars, however, the observed values of C_1' must be corrected for the large colour excess in the polar region. This operation, however, removes all the colour excess and gives for ΔC_1 a value which is too large by the amount of the unknown colour excess in the standard C_{1s}. This small quantity we denote by e_1, and in using (5) for NP stars replace the left member by $\Delta C_1 - e_1$. With allowance for reduction of the spectra to the HD system, we thus find

Group	NGP	SGP	KB	NP
No. stars	66	43	37	72
$z = \Delta C_1$	−0·012	+0·010	−0·042	$-0{\cdot}027 - e_1$

(6)

Since e_1 is probably of the order of +0·02 mag., we adopt

$$z = C_1 - C_1' = -0{\cdot}02 \text{ mag.} \tag{7}$$

From (2) and (5), therefore, for "unobscured" Ao stars,

$$C_1 = -0{\cdot}11 - \Delta C_1, \tag{8}$$

to which, for the NP group, the term $+e_1$ must be added to the right-hand member. Further, from equations (4) and (7) (for early-type stars only; for the spectral range as a whole the relationship is not linear),

$$C = 1{\cdot}90\, C_1 + 0{\cdot}015. \tag{9}$$

Including C_{1s} from (2), we therefore have, altogether,

Group	Standards	NGP	SGP	KB	NP
C_1	−0·09	−0·098	−0·120	−0·068	$-0{\cdot}083 + e_1$
C	−0·156	−0·171	−0·213	−0·114	$-0{\cdot}143 + 1{\cdot}9e_1$

(10)

or in the mean, for "unobscured" HD Ao stars,

$$C_1 = -0{\cdot}09 \text{ mag.}, \qquad C = -0{\cdot}15 \text{ mag.} \tag{11}$$

Freed from the small neglected colour excess, these results probably would be −0·11 and −0·19 mag., respectively. The latter value is 0·04 smaller than that given by the polar stars when completely freed from colour excess (Table II). The difference, however, is within the inherent uncertainty, as will appear in a moment.

Apart from the agreement to be expected from comparisons of this kind, the values of C_1 in (10) contribute nothing new. The value of z depends upon C_{1s}, and the computed values of C_1, in turn, on z. The mean C_1 must therefore be the same as the value of C_{1s}. The last two values of C_1 (based on Keenan-Babcock spectra) are systematically larger than the second and third (Mt. W. spectra) by 0·04 mag., an amount considerably in excess of the uncertainty arising from the photo-electric measurements. The discrepancy is probably largely due to a residual systematic difference in the spectra. Although both series have been reduced to the HD system, a remaining difference of one classification unit (which would account for 0·03 mag.) is possible.

The last four values of C are all independent and new. They do not involve z since they may be found by substituting the observed values of C_1' directly into equation (4). The first C, however, does depend on z, but its value necessarily equals the mean of the last four. All the C's, however, are subject to a systematic error arising from the uncertainty in the numerical terms in equation (4). From this source alone the mean error of C in (11) is ±0·03 mag., which accounts for the discrepancy between the "unobscured" value (11) and the −0·15 mag. in Table II, free from all colour excess, given by the polar stars.

Martin's colours for Ao stars, in so far as they depend on Mount Wilson colour

indices at least, are affected by an underestimate of the absorption and by the neglected magnitude error. With allowance for these circumstances, the mean result should agree with that in Table II. His value −0·06 mag. derived from the Greenwich gradient by correcting for line absorption * is not directly applicable to the discussion. Its zero point is fixed, not by reference to the standards that define the international system, but by the assumption that the gradient G should be zero for a certain group of Ao stars.

As matters stand at present, any inference to be drawn from the gradients is most easily obtained, not through the line absorption, but from G itself. For a larger group of Ao stars than was used to fix the zero point, $G = +0{\cdot}04$. From the correlation diagram for G and C_1 (Stebbins and Huffer) given by Atkinson, Hunter, and Martin †, the equivalent C_1, roughly scaled from the diagram, is $-0{\cdot}13$, whence, by equation (9) above, $C = -0{\cdot}23$. This value, although only approximate, falls in line with the other evidence on the colours of "unobscured" Ao stars.

Mount Wilson Observatory,
Carnegie Institution of Washington:
1943 *August* 23.

* Martin seems inadvertently to have applied the correction with the wrong sign. The colour index corresponding to the Ao gradient should be +0·10 mag.

† *M.N.*, 100, 206, Fig. 3, 1940.

STANDARD MAGNITUDES AT −45° DECLINATION

R. H. Stoy

(Communicated by H.M. Astronomer)

(Received 1943 August 16)

Summary

This paper is concerned with the derivation of standard photographic and photovisual magnitudes for about 250 stars between the seventh and tenth magnitudes in the Harvard E regions. The first part of the paper describes the experimental procedure and the establishment of a set of provisional magnitudes, while the second part deals with the comparison of these provisional magnitudes with other available magnitudes and with their reduction to the international system. The resulting magnitudes are given in Table I. Their probable error as determined from external comparisons is about $\pm 0^{m}.05$; that determined from the internal consistency is considerably smaller than this.

The magnitudes are based on two series of plates. The plates of the first series were taken through diffraction gratings and were used to establish a magnitude sequence in each of the nine regions. These sequences were reduced to a common scale and zero point by means of the plates of the second series, each plate of which intercompared two of the E Regions. The magnitudes of about forty stars in each of the Pleiades, the Hyades and Praesepe were then determined on this system to furnish the material for its reduction to the international system. This reduction was not as satisfactory as it might have been, due partly to the surprising lack of well-established photovisual magnitudes on the international scale for these much observed clusters and partly to the insufficiency of the data for determining the correction terms of the form $p(m - m_0)\ C.I.$

An examination of the colour indices of about 3000 stars whose magnitudes have been determined on this system discloses for each spectral type a variation of colour index with apparent magnitude. This variation was first suspected from the way in which the grating constant appeared to vary with the colour.

A comparison of the photographic magnitudes with the Harvard magnitudes ($Pg(H)$) and with those given in the two Cape Astrographic Zone Catalogues ($Pg(h)$) yields the probable errors of all three sets of magnitudes and the relations of the latter to the international system. In so far as these relations can be expressed by simple linear formulæ they are

$$\begin{aligned} Pg(H) &= 1{\cdot}124 IPg - 0{\cdot}07\ C.I. - 0{\cdot}94 \qquad (7 < m < 11), \\ Pg(h) &= 0{\cdot}967 IPg - 0{\cdot}21\ C.I. + 0{\cdot}16 \qquad (7 < m < 9) \\ &= 1{\cdot}259 IPg - 0{\cdot}21\ C.I. - 2{\cdot}18 \qquad (9 < m < 11), \end{aligned}$$

while the probable errors appear to be about $\pm 0^{m}.12$ for $Pg(H)$, of which $\pm 0^{m}.10$ can be attributed to the zero point and about $\pm 0^{m}.16$ for $Pg(h)$, of which $\pm 0^{m}.09$ is due to the zero point.

Introduction.—The work reported here was an attempt to provide a solid foundation for a much larger undertaking, viz. the determination of the photographic and photovisual magnitudes for all stars south of −30° declination whose positions and proper

motions are being determined photographically at the Cape Observatory. This is, of course, the southern counterpart of the photographic revision of the A.G. Zones now being carried out in the northern hemisphere. The majority of the stars involved have visual magnitudes between 7 and 10.

The magnitudes given in *H.A.*, **89**, 1, 1932, were to have been used as standards, but it quickly became apparent that they could not be used without some modification. This was partly because of the large colour difference between the instrumental equipment used at Harvard and that used at the Cape. A subsidiary programme was therefore undertaken to determine this colour difference and to check the methods being used in the zone work. As the work progressed, however, it appeared more and more desirable to use this observational material to deduce a completely independent system of magnitudes and to connect it as directly as possible with the international system.

Throughout this subsidiary programme, the exposures and methods employed have been identical with those used for the stars in the −30° to −35° zone which were observed and reduced concurrently.

Experimental Procedure.—The photographic and photovisual plates are taken simultaneously in two cameras mounted side by side. These cameras are fitted with five-inch aperture four-component lenses, specially designed and manufactured by Messrs. Taylor, Taylor and Hobson. They were designed to cover a field 15° square, but were stopped down by the makers to cover a field even larger than this without any vignetting. The effective apertures of the lenses as actually used were 3·5 inches for the photographic lens and 3·4 inches for the photovisual one. Both lenses have a focal length of approximately 35 inches. Over the whole of the field covered by the 8- by 10-inch plates which were used, the images approach perfection. The photographic lens is corrected for $H\gamma$, the photovisual lens for the D lines. It is hoped to publish a more detailed account of these lenses, their colour curves, distance corrections, etc., in a separate paper.

The cameras are mounted on the substantial equatorial stand of the old six-inch*, the driving clock of which has been renovated and fitted with an electric slow motion. All exposures were guided, even though the driving clock is reliable. The guiding telescope, a Cooke 6-inch of focal length 80 inches, is fitted with the usual moving eyepiece and scales so that the plates can be accurately centred on any chosen point and the brightest star in the vicinity used for guiding.

Two objective gratings for these cameras were made in the observatory workshop. That for the photographic lens has a wire plus space interval of 1·59 mm., while that for the photovisual has this interval equal to 1·99 mm. The distance between the centre and first order images is approximately 0·26 mm. on the photographic plates and 0·25 mm. on the photovisual ones. The computed grating constants are 2·14 and 2·02 magnitudes respectively. The gratings are so marked that they can be put on always in the same position. They can be interchanged.

Ilford Zenith plates were used for the photographic magnitudes and Ilford Hypersensitive Panchromatic behind a Kodak Wratten Filter No. 12 (Minus Blue) for the photovisual magnitudes. Both of these plates cover a rather wider spectral range than is really desirable for accurate photometry on account of the change of effective wavelength with spectral type. They were adopted for use only after experiments had shown that the exposure time required to get the faintest stars was quite prohibitive for such combinations as the Wratten No. 12 filter in front of an Ilford Chromatic, an Iso-Zenith or a Panchromatic plate for the photovisual and a Kodak Wratten No. 34 D in front of an Ilford Special Rapid or Zenith plate for the photographic. For the same reason extrafocal photometric methods were not adopted. All the plates were tank developed in amidol.

The plates were measured in a Schilt photometer manufactured by W. C. 't Hart and Son of Rotterdam and purchased by the Observatory in 1932. This photometer

* Gill, *History of the Cape Observatory*, xlii, London, 1913.

was satisfactory for short series of measurements, but it had to a very marked degree the defect noted by Bok in a similar instrument at Harvard *, viz. that the relation between the measured quantity and the magnitude of the star being measured did not remain constant, even for a single plate. The reason for this instability seems to have been largely mechanical, and has probably been eliminated in later models. A more fundamental difficulty, however, arose from our geographical position and the inherent sensitivity of the thermopile-galvanometer system to atmospheric disturbances, which made the use of the photometer practicable only in calm weather. Such periods of calm are exceptional at the Cape, which is notorious for its violent winds.

In 1941 the thermopile of the photometer was replaced by a photronic cell and radical structural alterations were made. The entire optical system (with the exception of the eyepieces) was mounted on a single casting which could be moved relatively to the plate carriage by one adjusting screw. The eyepieces were kept entirely separate from this casting and mounted on a heavy pillar so that the inevitable bumps that the eyepieces receive in the course of measuring a long plate should not upset the adjustment of the instrument. The original cylindrical rod and wheel mounting of the plate carriage was replaced by two large ball bearings running between V girders. The carriage was fitted with small adjusting screws so that the average plane of the part of the plate to be measured could be rapidly adjusted so as to remain in focus when the carriage is moved. This minimises the number of adjustments of focus that have to be made in the course of measurement. The method of viewing the plate grain under high magnification was rebuilt and made completely independent of the low-power viewing system with which the star image is located and centred. By the new arrangement the individual plate grains can be seen clearly and the plate kept in perfect focus.

The photronic cell was made up as a unit interchangeable with the thermopile. A short focus lens spreads a large out of focus patch of light over the cell, thus ensuring that the greater part of the sensitive surface is utilised and also that the light intensity is kept so low that the response from the cell is linear. It also avoids any difficulty that might arise from possible local variations in the sensitivity of the surface of the cell. The same galvanometer is used as for the thermopile, a resistance of about 80 ohms being used in parallel with the cell to ensure that the galvanometer is critically damped. (With the thermopile a resistance of about 60 ohms has to be used in series to obtain a suitable sensitivity.) It had been intended to use the thermopile on calm days, but the photronic cell proved so satisfactory that it is now used all the time. The galvanometer deflexion is perfectly steady, even when the fiercest south-easter gale is raging outside, while the zero of the galvanometer scale shows very little tendency to creep during measuring, a disconcerting habit it has whenever the thermopile is being used.

At the beginning of the zone programme the linear co-ordinate scales attached to the plate carriage were replaced by drums attached to the handles that operate the plate carriage. These drums are so graduated that direct use can be made of the co-ordinates of the stars computed for the positional work.

The normal routine for measuring a plate is as follows. After the plate has been centred, orientated and focused, the galvanometer scale is adjusted to zero for complete blackness; the resistance in the standard lamp circuit is then adjusted until the background reading is about 165 mm., and thereafter not usually touched until the measurement of the plate is complete. A sensitive voltmeter provides a check on the behaviour of the battery.

A background reading—which is either the mean of three or four quick settings or, more usually, a mean obtained by trailing the plate slowly—is taken with every star and recorded to the nearest mm. The reading for the star is made to the nearest 0·1 mm. This reading is reduced to a provisional magnitude by means of tables whose construction will be described later. They resemble the Leiden Table prepared by Wesselink†,

* *Harv. Reprints*, 77, 12, 1932. † *B.A.N.*, 8, 333, 1939.

but they are calculated for a range of background readings to avoid the necessity of continually tampering with the lamp circuit in order to bring the background reading to a certain definite assigned value.

Theory of the Reduction of the Measures of the Grating Plates.—Before the construction of the reduction tables, the galvanometer scale reading for a star image was always expressed as a percentage of that for the corresponding background. Let S represent such a reduced scale reading for the central image and S' the mean of those for the two side images. Then from the observed relation between $S'-S$ and S we have to try to find a function of S that will give the corresponding value of m. In other words, given

$$S'-S=\xi(S), \tag{1}$$

we have to try to find $m(S)$, which is such that

$$m(S')-m(S)=g, \tag{2}$$

where g is the grating constant.

This problem has been discussed and solved in various ways by different workers, their general method being based on that of Schwarzschild.* The solution that we have used is that implicit in Wesselink's paper.†

Following Schwarzschild, the relations (1) and (2) are first rendered symmetrical by introducing the variable T defined by

$$S'+S=2T.$$

If the relationship between $S'-S$ and S is expressed in the form

$$S'-S=\eta(T)$$

we have

$$S=T-\tfrac{1}{2}\eta(T),$$
$$S'=T+\tfrac{1}{2}\eta(T),$$

and we have to find m which is such that

$$m(T+\tfrac{1}{2}\eta(T))-m(T-\tfrac{1}{2}\eta(T))=g.$$

It is easy to show that as far as terms up to the third order are concerned, a solution of this equation valid round the point T_0, the value of T for which $\eta(T)$ is a maximum, is

$$m-m_0=A\tan\frac{B}{\eta_0}(S-T_0),$$

where A and B satisfy

$$B\tan\frac{B}{2}=-\tfrac{1}{4}\eta_0\eta_0'', \qquad 2A\tan\frac{B}{2}=g.$$

If the observed function $\eta(T)$ is put in the form

$$S'-S=\eta(T)\equiv\alpha-\beta(T-T_0)^2; \qquad \eta_0=\alpha; \qquad \eta_0''=-2\beta,$$

and A and B will be given by

$$A=\tfrac{1}{2}g\cot\frac{B}{2}=\frac{gB}{\alpha\beta}, \qquad B\tan\frac{B}{2}=\tfrac{1}{2}\alpha\beta.$$

The values of A and B depend only on the product $\alpha\beta$, and can be found immediately from two graphs on which corresponding values of $\alpha\beta$ and A and of $\alpha\beta$ and B have been plotted.

The actual procedure for reducing a plate is thus quite simple. The differences $S'-S$ are first plotted against S and a smooth curve drawn through the points so obtained. The maximum value of $S'-S$, η_0 (or α) is noted and also S_0, the corresponding value of S. Values of $S'-S$ and S are read off from this curve at regular intervals of S and from these values the value of $d^2\eta/ds^2$ at S_0 is obtained. This is -2β, since at this point $d^2\eta/dS^2=d^2\eta/dT^2$ as $d\eta/dS=0=d\eta/dT$. Having the values of

* *A.N.*, **172**, 65, 1906. † *B.A.N.*, **8**, 333, 1939.

α and β, the corresponding values of A and B are read off from the appropriate graphs (or tables).

This process was applied to eighteen pairs of grating plates of the E regions and to twelve pairs of plates of the $-30°$ to $-35°$ zone. In a few cases it was found that the $S'-S$, S curve was a straight line and advantage was taken of the exact solution given by Schwarzschild in the case when $\eta(S)$ is a linear function of S. This solution is

$$m = g\frac{\log(S-a)}{\log b},$$

the $S'-S$, S relation having been put into the form

$$S'-a = b(S-a).$$

In all cases the deduced solution was used only to give the central portion of the reduction curve, the ends being filled in from the $S'-S$, S curve. For both the visual and the photographic gratings the constant g was taken as 2·00 magnitudes.

For each of these sixty reduction curves the values of m corresponding to $S=5$, 10, 15 . . . were read off and tabulated. These values were then made comparable as regards zero point and scale, by putting $m_{50}=9{\cdot}40$ and making $m_{70}-m_{30}$ the same for each set. The means of the values of m corresponding to each S were then taken, slightly more weight being given to the values obtained from the zone plates for which the $S'-S$, S curves were based on many more points than were those of the E region plates. It was found that the mean m, S curves were symmetrical about the point of inflexion and could be well represented by

$$\begin{aligned} m-m_0 &= 2{\cdot}133\tan(1°{\cdot}129(S-49{\cdot}4)), \qquad \text{(photo)} \\ &= 2{\cdot}081\tan(1°{\cdot}140(S-52{\cdot}0)), \qquad \text{(visual)} \end{aligned}$$

the range of validity being from $S=10$ to $S=90$. These formulæ were used as the basis of the reduction tables used for all the subsequent plates. It may be recalled that the formula representing Wesselink's table is not symmetrical about the point of inflexion. The lower half of his mean reduction curve is

$$m-m_0 = 2{\cdot}397\tan(0°{\cdot}978(S-54{\cdot}0)), \qquad 16 < S < 54,$$

and the upper half

$$m-m_0 = 1{\cdot}889\tan(1°{\cdot}229(S-54{\cdot}0)), \qquad 54 < S < 92.$$

When the individual reduction curves were compared with the mean curve it was found that the deviations were rather larger than those found by Wesselink. In some cases this deviation might have been due to the poor determination of the $S'-S$, S curve for the individual region concerned, but in other cases the deviation was undoubtedly real. It was therefore of some importance to find a way of deriving the individual reduction curves from the mean one. The solution was simple. The provisional magnitude derived from the mean curve (or table) was regarded as S. The resulting $S'-S$, S curve could always be satisfactorily represented by the straight line

$$S'-S = c+\gamma(S-9{\cdot}4),$$

where γ is a small quantity. The corresponding solution is

$$\begin{aligned} m-m_0 &= \frac{g}{\log(1+\gamma)}\log\left(1+\frac{\gamma}{c}(S-9{\cdot}4)\right) \\ &= \frac{g}{\log(1+\gamma)}\left\{\frac{\gamma}{c}(S-9{\cdot}4)-\frac{\gamma^2}{2c^2}(S-9{\cdot}4)^2+\ldots\right\}. \end{aligned}$$

$\frac{g\gamma}{c(\log(1+\gamma))}$ is made equal to unity by the process of correcting the scale, so that the correction to the provisional (or tabular) magnitudes is

$$-\frac{\gamma}{2c}(S-9{\cdot}4)^2,$$

while the new value for the grating constant is

$$S'_{\text{cor}}-S_{\text{cor}}=c-\frac{\gamma}{2c}c^2=c-\frac{\gamma c}{2}.$$

It is worth noticing that, while it is natural to take the point of inflexion of the reduction curve as the central point for these corrections, it is not necessary to do so. The error involved in taking some other point which may be more convenient is (after the zero point and scale have been corrected), of the order of

$$\frac{\gamma^2}{2c^2}(S-m')^2,$$

where m' is the adopted central point. This will be negligible as γ/c is small.

The Observations.—The original programme for the observation of the E regions consisted of two parts: the first a series of grating plates from which it was intended to derive the grating constants, and the second a series of intercomparison plates to check the consistency of the zero point of the Harvard magnitudes.

In carrying out the first part of this programme, two grating plates were obtained of each region, one of these usually being with the camera east of the pier, the other with it west. The exposure time was 30 mins., except for a few cases when it was 45 mins. These plates were reduced in the manner already described. The provisional magnitudes so obtained were then reduced to the scale and zero point of the Harvard sequence for that particular area by direct comparison of the magnitudes of the stars in common, the final adjustment being made by a least square solution. The average arithmetical difference between the determinations of the magnitude of a star on the two plates is $0^{m}{\cdot}06$ for the photographic and $0^{m}{\cdot}07$ for the photovisual. The values deduced for the grating constants, however, were not so encouraging. They averaged 2·06 for the photographic and 1·97 for the photovisual, compared with the computed values of 2·14 and 2·02. As the values of these constants from the individual plates varied from 1·86 to 2·25 for the photographic and 1·66 to 2·20 for the photovisual, and as large differences appeared as likely to occur between the values from plates of the same region as between plates of different regions, the conclusion was drawn that the grating constant could not be regarded as a constant and no further use was made of it. Instead, as a working hypothesis, it was assumed that for any given plate the measured difference between side and central image was constant, the value of this constant depending largely on how the plate was measured. In passing it may be remarked that this value seems to depend mainly on the relative sizes of the star image and the analysing diaphragm.* In what follows, it will be convenient to refer to the system of magnitudes derived from these grating plates and reduced region by region to the corresponding Harvard scale and zero point as the m'' system.

To carry out the second part of the programme each of the nine E regions was compared directly with each of the three preceding and with each of the three following regions. The general scheme of these intercomparisons is shown in fig. 1. Only

* For example, a photographic plate of the Pleiades gave $2^{m}{\cdot}20$, $2^{m}{\cdot}00$ and $1^{m}{\cdot}90$ as the value of the grating constant, corresponding to measures with the small, medium and large diaphragms. The diameters of the projections of these diaphragms on the plate are approximately 0·08, 0·12 and 0·24 mm. The medium diaphragm is the one which is used for routine measurement.

27 pairs of plates were needed, but a dozen or so of these intercomparison plates were obtained in duplicate. All these plates were taken on a fixed system and were so timed that the two regions being compared were at exactly equal zenith distances at the time of mid-exposure. Two exposures of three minutes were given to the first region, then four to the second region and finally two more to the first region. Wherever possible the plates were left in the camera for some time before the exposures were made in order to allow the plates to adjust themselves to the temperature and humidity of the air.

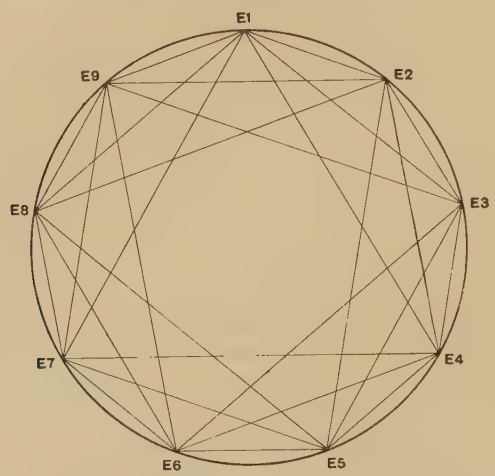

FIG. 1.—*Arrangement of the Intercomparison Plates.*

A preliminary adjustment of the m'' magnitudes was attempted after about two-thirds of the comparison plates had been obtained. The measures of the two regions on each plate were treated independently, and linear formulæ of the type

$$m_{\text{Tab}} - m'' = a \, . \, m_{\text{Tab}} + b$$

were derived by means of least square solutions, m_{Tab} being the magnitude in the reduction tables corresponding to the mean of the measures of the four images of each star. The relation between the m'' magnitudes of the one region and those of the other were then derived. These relations were used to reduce the m'' sequences to a common scale and zero point. This reduction was made by making the magnitudes in the individual sequences which corresponded to two chosen magnitudes in the E2 sequence (7·5 and 9·5 photographic; 7·0 and 9·0 photovisual) coincide with their mean value for all the sequences. (E2 was chosen as a temporary base because at that time it was the region that was directly connected with the greatest number of other regions.) Before this transformation was carried out the individual m'' magnitudes were corrected by the amount indicated by the mean of the residuals from the least square solutions. The reduction was checked by plotting the magnitudes thus derived against the tabular magnitudes for each of the comparison plates, both regions on the plate being taken together. It was immediately evident from the graphs that the reduction to a homogeneous system had been successfully accomplished. Straight lines were drawn through the plotted points and were used to reduce the tabular magnitudes. The results for each star were collected together and a straight mean taken. The magnitudes so obtained were used as the basis of the final approximation. They will be referred to as the m''' magnitudes.

For this final approximation, all the available comparison plates, including both those that had been used in obtaining m''' and those which had been obtained subsequently, were reduced by a method similar to that employed in obtaining m''', except

that instead of plotting m''' against m_{Tab}, $m_{\text{Tab}} - m'''$ was plotted against m_{Tab}, the scale used for $m_{\text{Tab}} - m'''$ being fifty times that used for m_{Tab}. Smooth curves which were often, though not always, linear were drawn through the plotted points and used to reduce m_{Tab}. The magnitudes obtained from these curves were gathered together by regions. The straight mean of the six determinations of magnitude for each star was taken as m^{IV}. These magnitudes, together with the colour indices derived from them, are shown in Table I under the headings *Pg*, *Pv* and *C.I.* When there was more than one plate comparing the same two regions only the mean results from these plates were entered on the appropriate sheet. This was done in order to prevent the zero point of one region having an undue effect on that of the other when the means were taken. The average arithmetical difference between each of the six determinations of magnitude (each of which is itself the mean of the measures of four or eight images) and the mean of the six is $0^{\text{m}}.031$ for both the photographic and photovisual plates, while the average difference in the zero point of a plate from the mean of the six is $0^{\text{m}}.013$ for the photographic and $0^{\text{m}}.009$ for the photovisual. Thus the internal evidence indicates a probable error of about $\pm 0^{\text{m}}.01$ for the individual m^{IV} magnitudes and of about $\pm 0^{\text{m}}.005$ for the zero point of the sequences. These probable errors include the effect of certain systematic errors which will now be discussed.

The Effect of Atmospheric Extinction.—Where necessary the correction for differential atmospheric extinction is applied in the form $m_0 \sec z \tan z dz$, where m_0 denotes the extinction at the zenith. Per degree this amounts to $0.01745\ m_0 \sec z \tan z$. The adopted values of m_0 were $0^{\text{m}}.48$ for the photographic plates and $0^{\text{m}}.31$ for the photovisual. These values were based on Abbot's * tables for the vertical transmission of the atmosphere above Washington and on the published spectral sensitivity of the plates and filter used.

The plates from which the m^{IV} magnitudes were determined were not corrected for differential extinction, as the total effect of these corrections on the mean would be negligible. Each m^{IV} magnitude is the mean of six determinations, three of which were made at hour angles of $1^{\text{h}}\ 20^{\text{m}}$, $2^{\text{h}}\ 40^{\text{m}}$ and $4^{\text{h}}\ 00^{\text{m}}$ east of the meridian and three at the same hour angles west of the meridian. The direction to the zenith corresponding to these hour angles makes angles of 29°, 6° and 8° with the east-west direction, *i.e.* with the axis of the x co-ordinates used to identify the position of the stars in each region. In the case of the two larger hour angles, therefore, the differential extinction will be practically proportional to the x co-ordinate and will be equal and opposite for plates taken on different sides of the meridian. This, too, is partially the case for the smaller hour angle, and, in addition, the amount of the differential extinction is so small ($0^{\text{m}}.003$ per degree for the photographic) that its effect on the mean, *i.e.* on m^{IV}, will be negligible.

As a matter of curiosity the residuals of the individual determinations were examined to see if they showed traces of this differential extinction. The differences between the residuals for the plates taken east of the meridian and those for plates taken west of the meridian were arranged according to the x co-ordinate of the individual stars. Other things being equal, these differences should show twice the effect of the differential extinction. The results obtained, after the mean of the differences for all the stars had been adjusted to zero, are shown in Table II, the x co-ordinate being on the scale of 100″ per mm.

As the probable error of the observed quantities varies between $0^{\text{m}}.01$ and $0^{\text{m}}.02$, the agreement between the observed and computed effect is on the whole very satisfactory, especially if it is remembered that the stars are not distributed over the plates regularly and that these residuals may also include other systematic effects depending on the position on the plate. The only possible discrepancy is for the photovisual plates taken at an hour angle of $2^{\text{h}}\ 40^{\text{m}}$.

It was necessary to adjust the mean of the differences for all stars to zero, as it will

* *Smith. Ap. O. An.*, **2**, 113, 1908.

TABLE I

Magnitudes of Stars in the Harvard Standard E Regions

Star	Sp.	*Pg(H)*	*Pv(H)*	*Pg*	*Pv*	*C.I.*	*Pg′*	*Pv′*	*Pg(h)*	*HPv*	*IPg*	*IPv*	*C.I.$_i$*
E1													
638 A	Fo	7·27	6·79	7·28	7·05	+0·23	7·32	7·00	7·5	7·30	7·40	7·07	+0·33
589 B	B9	7·45	7·85	7·66	7·94	−0·28	7·70	7·97	7·9	8·93	7·68	7·91	−0·23
655 C	Ko	7·56	6·16	7·38	6·09	+1·29	7·38	6·06	7·6	6·22	7·59	6·26	+1·33
738 D	G5	7·70	6·81	7·76	6·81	+0·95	7·78	6·80	7·8	6·78	7·89	6·94	+0·95
632 E	Fo	7·76	7·37	7·78	7·45	+0·33	7·74	7·45	8·2	7·55	7·84	7·50	+0·34
705 F	F2	8·30	7·87	8·25	7·88	+0·37	8·20	7·82	8·6	7·83	8·25	7·92	+0·36
578 G	F5	8·51	8·36	8·80	8·36	+0·44	8·81	8·28	9·0		8·76	8·40	+0·36
676 H	Ko	8·60	7·03	8·41	6·69	+1·72	8·45	6·70	8·0		8·56	6·93	+1·63
773 I	F2	8·84	8·30	8·56	8·11	+0·45	8·54	8·13	8·4	7·86	8·55	8·17	+0·38
602 K	F2	8·99	8·68	9·02	8·58	+0·44	9·04	8·51	9·2	8·25	8·96	8·62	+0·34
651 L	Ko	9·25	7·75	9·17	7·48	+1·69	9·20	7·56	9·0		9·24	7·74	+1·50
618 M	A2	9·65	9·55	9·82		0·00	9·67	9·67	9·8		9·55	9·67	−0·12
606 N	G5	10·13	9·01	10·00	8·79	+1·21	9·97	8·77	10·0		9·89	8·96	+0·93
634 O	Go	10·40		10·33		+0·55	10·19	9·64	10·4		10·04	9·72	+0·32
f 400 P	G5	10·58	9·53			+0·87	10·35	9·48	10·5		10·19	9·60	+0·59
Q	G5	10·64	9·87			+0·64	10·46	9·82			10·26	9·91	+0·35
R	K2	10·94	9·61			+1·59	10·76	9·17			10·63	9·39	+1·24
594	G5			8·91	7·83	+1·08	8·94	7·95	9·0		8·94	8·01	+0·93
604	K2			8·17	6·47	+1·70	8·19	6·44	8·1	6·58	8·34	6·70	+1·64
637	A2			8·63	8·47	+0·16	8·52	8·49	8·8		8·55	8·49	+0·06
677	Ao			7·76	7·82	−0·06	7·76	7·79	7·9		7·78	7·80	−0·02
706	F5			8·67	8·15	+0·52	8·65	8·15	8·8		8·66	8·22	+0·44
726	Ko			8·60	7·71	+0·89	8·58	7·74	8·8		8·63	7·84	+0·79
E2													
2125 A	Go	7·22	6·69	7·23	6·78	+0·45	7·26	6·76	7·3	6·70	7·37	6·84	+0·53
2040 B	A5	7·54	7·36	7·72	7·58	+0·14	7·74	7·56	8·1		7·77	7·60	+0·17
2023 C	Ao	7·61	7·42	7·74	7·68	+0·06	7·75	7·63	8·0	7·50	7·78	7·68	+0·10
1977 D	G5	7·64	6·78	7·88	6·63	+1·25	7·85	6·68	7·6	6·68	8·02	6·82	+1·20
1997 E	G5	7·98	7·34	8·16	7·10	+1·06	8·16	7·14	8·5		8·26	7·26	+1·00
2007 F	A2	8·16	8·17	8·27	8·24	+0·03	8·26	8·26	8·3	8·26	8·24	8·24	0·00
1948 G	F8	8·44	8·20	8·58	8·10	+0·48	8·64	8·14	8·5		8·58	8·18	+0·40
1947 H	Ko	8·44	7·52	8·66	7·33	+1·33	8·67	7·42	8·7	7·46	8·74	7·54	+1·20
2014 I	Go	8·54	8·01	8·71	8·03	+0·68	8·67	8·08	9·0	8·12	8·69	8·14	+0·55
2013 K	B9	8·66	8·81	8·89	8·88	+0·01	8·86	8·82	9·0		8·78	8·86	−0·08
1994 L	F8	8·74	8·48	8·92	8·45	+0·47	8·90	8·28	9·1		8·87	8·48	+0·39
2054 M	Go	8·80	8·29	8·90	8·28	+0·62	8·86	8·26	9·0		8·86	8·37	+0·49
2022 N	Go	8·97	8·37	9·14	8·39	+0·75	9·16	8·31	9·2		9·09	8·48	+0·61
1988 O	Go	9·29	9·21	9·45	9·01	+0·44	9·43	8·85	9·3	8·97	9·34	9·03	+0·31
f 1191 P	K2	9·52	7·70:	9·48	7·68	+1·80	9·56	7·67	9·8	8·17	9·54	7·93	+1·61
2016 Q	Ko	9·58	8·71	9·71	8·59	+1·12	9·67	8·61	9·9	8·82	9·62	8·75	+0·87
1974 R	Go	9·65	9·00	9·93	8·91	+1·02	9·83	8·74	10·1		9·78	9·01	+0·77
2021 S	Go	9·92	9·37	10·05		+0·74	9·95	9·21	10·1		9·85	9·31	+0·54
1996 T	G5	9·93	9·60			+0·99	9·95	8·96	10·4		9·85	9·10	+0·75
f 1149 U	Ko	10·30	9·40			+1·11	10·29	9·18	10·7		10·16	9·34	+0·82
f 1181 V	K2	10·59				+0·88	10·66	9·78	11·0		10·47	9·90	+0·57
1929	Ko			8·90	7·73	+1·17	8·98	7·80	8·9		8·95	7·91	+1·04
1935	Ao			6·97	7·00	−0·03	6·97	6·98	7·2	6·80	7·08	7·00	+0·08
1968	F5			8·41	7·98	+0·43	8·38	7·97	8·2		8·41	8·04	+0·37
2058	G5			7·44	6·47	+0·97	7·44	6·52	7·7	6·25	7·61	6·62	+0·99
2061	A5			8·56	8·27	+0·29	8·59	8·25	8·4		8·54	8·31	+0·23
2074	Fo			6·89	6·60	+0·29	6·90	6·57	7·4	6·31	7·04	6·63	+0·41
2104	Ko			8·14	6·46	+1·68	8·07	6·51	8·5	6·50	8·19	6·71	+1·58
2107	Fo			8·88	8·52	+0·36	8·82	8·54	8·9	8·57	8·81	8·57	+0·24

TABLE I—*continued*

Star	Sp.	*Pg(H)*	*Pv(H)*	*Pg*	*Pv*	*C.I.*	*Pg'*	*Pv'*	*Pg(h)*	*HPv*	*IPg*	*IPv*	*C.I.*$_i$
E3													
3904 A	A3	7·44	7·37	7·50	7·48	+0·02	7·56	7·47	7·7	7·48	7·57	7·48	+0·09
3765 B	B8	7·46	7·63						7·5				
3763 C	Ao	7·59	7·50	7·49	7·70	−0·21	7·52	7·70	7·6		7·54	7·67	−0·13
3746 D	Ao	7·72	7·63	7·63	7·78	−0·15	7·64	7·81	7·9		7·65	7·77	−0·12
3738 E	B9	8·00	7·94	7·98	8·19	−0·21	7·96	8·19	7·9	7·89	7·96	8·16	−0·20
3740 F	B9	8·16	8·30	8·22	8·38	−0·16	8·19	8·36	8·3		8·17	8·36	−0·19
3758 G	Ao	8·47	8·57	8·35	8·25	+0·10	8·35	8·28	8·2		8·32	8·27	+0·05
3809 H	A3	8·99	8·51	8·93	8·71	+0·22	8·96	8·79	8·7	8·58	8·86	8·76	+0·10
3811 I	Fo	9·38	8·73	9·26	9·03	+0·23	9·25	9·07	8·8	8·84	9·15	9·07	+0·08
3880 K	K5	9·62		9·38	7·69	+1·69	9·36	7·68	9·0	8·11	9·42	7·93	+1·49
3871 L	G5	9·67		9·55	8·94	+0·61	9·49	9·07	9·0		9·43	9·06	+0·37
3788 M	K2	9·80		9·56	8·46	+1·10	9·50	8·46	9·0		9·49	8·61	+0·88
3824 N	F8	10·18		9·97		+0·29	9·95	9·66	9·6		9·77	9·70	+0·07
f 2337 O	F8	10·24		10·15		+0·20	9·95	9·75	9·9		9·82	9·78	+0·04
3771 P	Go	10·26				+0·32	9·96	9·64	9·3		9·78	9·68	+0·10
f 2836 Q	Ao	10·50				−0·19	10·14	10·33	10·3		9·88	10·30	−0·42
f 2401 R	Ao	10·91				0·00	10·59	10·59:	10·7		10·31	10·59:	−0·28:
S		10·91				+0·70	10·48	9·78:			10·29	9·88:	+0·41:
T		11·39				+0·88	10·99	10·11:			10·76	10·23:	+0·53:
3676	Ao			8·15	8·12	+0·03	8·17	8·14	8·2		8·13	8·12	+0·01
3697	Fo			8·84	8·61	+0·23	8·87	8·62	8·5		8·79	8·64	+0·15
3726	Ao			8·62	8·60	+0·02	8·65	8·55	8·4		8·56	8·59	−0·03
3755	F2			8·69	8·29	+0·40	8·66	8·30	8·4		8·65	8·35	+0·30
3768	Ao			8·42	8·49	−0·07	8·37	8·56	8·5		8·35	8·50	−0·15
3802	G5			9·30	8·65	+0·65	9·32	8·64	9·0		9·23	8·74	+0·49
3840	A2			8·44	8·33	+0·11	8·40	8·31	8·2		8·39	8·35	+0·04
3851	G5			9·05	7·98	+1·07	9·09	8·05	8·9		9·06	8·15	+0·91
3971	F8			9·40	8·89	+0·51	9·36	8·85	8·9	8·71	9·30	8·95	+0·35
3972	Go			8·93	8·28	+0·65	8·90	8·24	8·4		8·89	8·36	+0·53
3980	G5			8·89	7·92	+0·97	8·95	7·89	8·7		8·91	8·05	+0·86
E4													
7303 A	G5	7·19	5·64	6·58	5·67	+0·91	6·57	5·63	7·0	5·88	6·84	5·79	+1·05
7385 B	Ao	7·69	7·31	7·44	7·60	−0·16	7·47	7·60	7·7		7·49	7·58	−0·09
7315 C	Ao	8·10	8·08	7·96	7·99	−0·03	7·98	8·07	8·0		7·96	8·01	−0·05
7462 D	Ko	8·13	6·61	7·79	6·40	+1·39	7·83	6·47	7·7	6·58	7·97	6·61	+1·36
7265 E	Ko	8·22	6·70	7·91	6·51	+1·40	7·90	6·48	7·6		8·07	6·70	+1·37
7380 F	A2	8·36	8·11	8·14	8·08	+0·06	8·13	8·06	8·2		8·13	8·09	+0·04
7474 G	A2	8·38	8·37	8·18	8·21	−0·03	8·19	8·23	8·2	8·22	8·16	8·21	−0·05
7389 H	A2	8·99	8·65	8·75	8·74	+0·01	8·76	8·62	8·4		8·67	8·72	−0·05
7368 I	A3	9·57	9·24	9·43		+0·29	9·44	9·15	9·5		9·30	9·19	+0·11
7337 K	Ao	9·63	9·78:	9·52		+0·06	9·49	9·43	8·9	9·52	9·35	9·44	−0·09
7369 L	Ao	9·75	9·89	9·75		+0·04	9·70	9·66	9·8	9·51	9·54	9·67	−0·13
7298 M	A2	9·97	9·66	9·88		+0·26	9·79	9·53	9·8	9·68	9·67	9·57	+0·10
7349 N	M*b*	10·04		9·58	7·61	+1·97	9·62	7·67	9·7	8·02	9·64	7·90	+1·74
f 6069 O	Ko	10·05	9·08	9·81		+1·16	9·83	8·67	9·9	8·71	9·74	8·83	+0·91
f 5960 P	Ao	10·20	9·99	10·04		+0·19	9·93	9·74	10·1		9·77	9·77	0·00
f 6084 Q	A3	10·52	10·31			+0·22	10·26	10·04	11·1		10·03	10·07	−0·04
f 6014 R	Go	10·77	10·03			+0·61	10·48	9·87	10·4		10·28	9·96	+0·32
f 6005 S	K5	11·02	9·43			+1·54	10·72	9·18	10·5		10·59	9·40	+1·19
T		11·18	10·09				10·82						
U		11·34	10·26				11·16						
V		11·44	10·52				11·21						
7144	F8			8·98	8·48	+0·50	8·98	8·41	8·6		8·93	8·53	+0·40
7232	Ao			8·44	8·48	−0·04	8·39	8·43	8·3		8·38	8·46	−0·08
7269	A2			8·08	8·09	−0·01	8·10	8·05	8·0		8·07	8·08	−0·01
7280	A2			7·69	7·73	−0·04	7·66	7·74	7·6		7·72	7·72	0·00
7292	A2			7·47	7·54	−0·07	7·50	7·54	7·8		7·53	7·53	0·00
7300	G5			8·62	7·52	+1·10	8·64	7·61	8·3		8·67	7·69	+0·98

TABLE I—*continued*

Star	Sp.	*Pg*(*H*)	*Pv*(*H*)	*Pg*	*Pv*	*C.I.*	*Pg′*	*Pv′*	*Pg*(*h*)	*HPv*	*IPg*	*IPv*	*C.I.*$_i$
E4 (*cont.*)													
7302	Ao			8·14	8·25	−0·11	8·11	8·25	8·0		8·11	8·23	−0·12
7318	A2			8·41	8·49	−0·08	8·43	8·51	8·2		8·35	8·48	−0·13
7336	Ao			8·16	8·31	−0·15	8·15	8·32	8·1		8·12	8·29	−0·17
7422	F8			8·56	8·11	+0·45	8·57	8·06	8·3		8·55	8·16	+0·39
7453	Go			8·00	7·55	+0·45	8·04	7·57	8·0		8·06	7·61	+0·45
7471	Fo			8·25	7·99	+0·26	8·23	8·03	8·0		8·25	8·04	+0·21
E5													
10100 A	Ao	6·91	6·91	7·24	7·41	−0·17	7·25	7·38	7·3	7·16	7·30	7·38	−0·08
10001 B	F8	7·22	6·38	7·13	6·62	+0·51	7·21	6·62	6·9	6·65	7·30	6·69	+0·61
10156 C	Ko	7·45	6·27	7·67	6·43	+1·24	7·54	6·39	7·3	6·32	7·82	6·59	+1·23
10248 D	B9	7·46	7·75	7·81	8·04	−0·23	7·77	8·12	7·7		7·79	8·03	−0·24
10118 E	Ao	7·65	7·67	7·98	8·14	−0·16	7·98	8·11	7·8		7·96	8·11	−0·15
10153 F	Go	7·89	7·06	8·04	7·44	+0·60	8·08	7·50	8·2		8·11	7·53	+0·58
10013 G	F8	8·19	7·34	8·35	7·77	+0·58	8·31	7·76	8·3		8·36	7·85	+0·51
10087 H	A2	8·43	8·27	8·70	8·61	+0·09	8·71	8·54	8·7		8·63	8·60	+0·03
9931 I	Fo	8·68	8·55	9·00	8·68	+0·32	9·02	8·65	8·8		8·93	8·71	+0·22
9976 K	A3	8·79	8·92	9·13		+0·30	9·15	8·85	9·1		9·04	8·89	+0·15
9966 L	A	9·33	9·51	9·66		+0·39	9·63	9·24	9·2	9·09	9·51	9·29	+0·22
9965 M	K5	9·61	8·30	10·00	8·22	+1·78	9·97	8·23	10·0	8·58	9·96	8·47	+1·49
f 9664 N	Ao	9·72	9·88	10·23		+0·30	10·16	9·86	10·1		9·97	9·90	+0·07
f 9636 O	A2	9·94	9·85			+0·38	10·32	9·94	10·1		10·10	9·99	+0·11
P	K2	10·25	9·19			+1·72	10·65	8·93			10·55	9·17	+1·38
Q		10·39	9·82			+0·36	10·74	10·38			10·48	10·43	+0·05
R		10·70				+1·98	10·92	8·94			10·82	9·22	+1·60
9954	Ao			9·00	8·62	+0·38	9·02	8·68	8·4		8·93	8·68	+0·25
9977	A2			9·01	8·79	+0·22	9·03	8·83	8·5		8·92	8·83	+0·09
9978	Ao			8·16	7·98	+0·18	8·11	8·05	7·7		8·15	8·03	+0·12
10010	G5			8·98	8·28	+0·70	9·01	8·26	8·5		8·96	8·38	+0·58
10140	F8			9·26	8·69	+0·57	9·18	8·67	9·0		9·16	8·77	+0·39
10145	A3			8·68	8·44	+0·24	8·71	8·40	8·5		8·64	8·46	+0·18
10160	F5			6·94	6·58	+0·36	7·02	6·51	7·1	6·52	7·11	6·61	+0·50
10166	Ao			8·70	8·58	+0·12	8·64	8·58	8·6		8·62	8·60	+0·02
10207	Ko			8·57	7·34	+1·23	8·52	7·40	8·3		8·64	7·53	+1·11
E6													
12505 A	F8	6·38	5·87	6·42	5·99	+0·43	6·43	5·99	6·6	6·11	6·64	6·05	+0·59
12743 B	B8	6·80	6·84						7·8				
12613 C	B9	6·83	6·66	6·82	7·00	−0·18	6·83	6·98	7·2		6·93	6·97	−0·04
12553 D	Ao	7·22	7·40	7·26	7·40	−0·14	7·26	7·45	7·4		7·32	7·39	−0·07
12628 E	G	7·39	6·28	7·36	6·16	+1·20	7·33	6·06	7·7	6·22	7·55	6·31	+1·24
12725 F	Go	7·68	7·10	7·70	7·11	+0·59	7·71	7·12	7·8		7·79	7·19	+0·60
12633 G	B9	7·98	7·88:	8·06	8·17	−0·11	8·01	8·15	8·3	8·05	8·03	8·15	−0·12
12752 H	Ao	8·51	8·25	8·53	8·63	−0·10	8·55	8·61	8·8		8·46	8·62	−0·16
12564 I	F5	8·56	7·92:	8·61	8·07	+0·54	8·63	8·00	8·5	8·28	8·60	8·13	+0·47
12521 K	F8	8·63	8·03	8·69	8·03	+0·66	8·62	8·08	8·7	7·83	8·67	8·13	+0·54
12610 L	Go	9·11	8·47	9·13	8·39	+0·74	9·17	8·35	9·0	8·68	9·09	8·48	+0·61
12606 M	Ao	9·20	9·15	9·31		+0·08	9·27	9·19	9·4	9·31	9·17	9·20	−0·03
12657 N	Ao	9·25	8·96	9·31		+0·19	9·28	9·09	9·2	9·18	9·18	9·12	+0·06
12716 O	A2	9·62	9·39	9·64		+0·25	9·65	9·40	9·3	9·31	9·50	9·44	+0·06
12603 P	A2	9·63	9·41	9·68		+0·44	9·75	9·31	9·6	9·45	9·58	9·37	+0·21
12460 Q	G	9·74	9·34	9·80		+0·65	9·81	9·16	9·8	9·34	9·68	9·25	+0·43
12711 R	A2	9·96	9·61	10·06		+0·48	10·08	9·60	9·6	9·71	9·89	9·67	+0·22
12411 S	B5	10·13	10·20			+0·19	10·23	10·04	10·3		10·00	10·07	−0·07
12645 T	Ao	10·15	10·16			+0·25	10·25	10·00	10·5		10·03	10·04	−0·01
12406 U	F2	10·43	9·73			+0·56	10·43	9·87	10·3		10·22	9·95	+0·27
V		10·76				+1·29	10·66	9·37			10·51	9·55	+0·96
W		10·84				+0·19	10·82	10·63:			10·53	10·66:	−0·13:
X	Ko	10·84				+1·38	10·73	9·35			10·58	9·54	+1·04

TABLE I—*continued*

Star	Sp.	*Pg(H)*	*Pv(H)*	*Pg*	*Pv*	*C.I.*	*Pg′*	*Pv′*	*Pg(h)*	*HPv*	*IPg*	*IPv*	*C.I.$_i$*
E6 (*cont.*)													
f 12408 Y	Ko	11·02				+1·13	10·99	9·86	10·9		10·78	10·02	+0·76
Z		11·12				+0·39	11·12	10·73:			10·82	10·78:	+0·04:
12468	Ao			8·87	8·84	+0·03	8·82	8·84	9·0		8·77	8·84	−0·07
12492	Ko			7·96	6·58	+1·38	8·01	6·61	7·6	6·65	8·12	6·78	+1·34
12516	Ao			8·07	8·11	−0·04	8·01	8·16	8·1		8·05	8·11	−0·06
12599	G5			8·44	7·34	+1·10	8·46	7·39	8·2		8·51	7·50	+1·01
12733	Ao			8·20	8·19	+0·01	8·17	8·23	8·4		8·17	8·20	−0·03
12737	G5			8·82	8·06	+0·76	8·83	8·07	8·9	8·16	8·81	8·17	+0·64
12740	A2			8·37	8·18	+0·19	8·35	8·20	8·5		8·35	8·21	+0·14
12766	G5			8·23	7·10	+1·13	8·29	7·05	8·5	7·46	8·33	7·25	+1·08
12768	A2			8·19	8·02	+0·17	8·24	8·07	8·2		8·20	8·05	+0·15
12776	A2			8·01	7·94	+0·07	8·04	7·95	8·3		8·03	7·95	+0·08
12783	Ao			6·68	6·85	−0·17	6·70	6·83	7·1	6·88	6·81	6·83	−0·02
12784	A2			7·60	6·97	+0·63	7·63	7·03	7·8		7·72	7·07	+0·65
E7													
16133 A	Fo	7·02	6·89	7·01	6·66	+0·35	6·93	6·66	6·7	6·76	7·14	6·71	+0·43
16035 B	Ao	7·38		7·30	7·33	−0·03	7·27	7·35	7·5	7·02	7·37	7·33	+0·04
16260 C	B8	7·41	7·63	7·45	7·64	−0·19	7·47	7·65	7·0		7·49	7·61	−0·12
16185 D	B8	7·62	7·77	7·83	7·97	−0·14	7·84	7·97	7·7	7·63	7·83	7·95	−0·12
16433 E	B8	7·94		8·08	8·18	−0·10	8·10	8·18	8·2		8·06	8·17	−0·11
16364 F	Bo	8·16		8·18	8·25	−0·07	8·23	8·33	8·1		8·16	8·26	−0·10
16348 G	B8	8·25		8·24	8·28	−0·04	8·24	8·27	8·2		8·21	8·27	−0·06
16157 H	A3	8·37	7·98	8·35	8·11	+0·24	8·31	8·17	8·3	8·11	8·33	8·15	+0·18
16091 I	B8	8·53	8·44	8·62	8·55	+0·07	8·64	8·50	8·6		8·56	8·55	+0·01
16158 K	Ko	8·86		8·88	7·40	+1·48	8·82	7·41	8·3	7·74	8·93	7·61	+1·32
16173 L	B8	8·90	8·69	9·14		+0·04	9·11	9·07	8·9		9·01	9·08	−0·07
16217 M	Ao	8·95	8·49	9·00	8·68	+0·32	8·94	8·65	8·7	8·64	8·91	8·71	+0·20
16092 N	Ko	8·99	7·85	9·05	7·66	+1·39	9·11	7·75	8·7		9·10	7·87	+1·23
16226 O	Ao	9·34	8·99	9·39		+0·13	9·37	9·24	9·5		9·25	9·26	−0·01
16258 P	Ao	9·41	9·19	9·50		+0·20	9·55	9·35	9·6	9·55	9·36	9·38	−0·02
16239 Q	Ao	9·42	9·09	9·54		+0·34	9·58	9·24	9·5		9·42	9·29	+0·13
16231 R	A5	9·52	9·03	9·63		+0·60	9·72	9·12	9·5	9·21	9·57	9·20	+0·37
16197 S	B8	9·85	9·71			+0·25	10·23	9·98	10·0		10·01	10·02	−0·01
16212 T	G5	9·86	9·02			+1·17	10·13	8·96	10·1	9·24	10·03	9·12	+0·91
16159 U	Ao	10·02				+0·30	10·23	9·93	10·1		10·01	9·97	+0·04
f 16531 V	Go	10·20				+0·67	10·57	9·90	10·7		10·36	9·99	+0·37
f 16585 W	B8	10·47				+0·44	10·93:	10·49	11·0		10·66:	10·55	+0·11:
f 16623 X	Ao	10·64				+0·29	10·98:	10·69	10·7		10·68:	10·73	−0·05:
f 16639 Y	Ao	10·73				+0·19	11·11:	10·92:	11·0		10·79:	10·95:	−0·16:
Z		10·92				+1·18	11·11:	9·93			10·90:	10·10	+0·80:
15961	A2			8·46	8·40	+0·06	8·44	8·38	8·7		8·42	8·41	+0·01
15986	F2			7·81	7·12	+0·69	7·85	7·15	7·8		7·92	7·23	+0·69
16210	G5			8·85	8·04	+0·81	8·82	8·06	8·4		8·84	8·15	+0·69
16221	G5			9·35	8·41	+0·94	9·40	8·43	9·0		9·31	8·54	+0·77
16254	F2			8·82	8·34	+0·48	8·82	8·35	8·2		8·78	8·41	+0·37
16325	Go			9·24	8·58	+0·66	9·26	8·53	9·1		9·17	8·66	+0·51
16383	Ao			8·85	8·82	+0·03	8·83	8·84	8·8		8·76	8·82	−0·06
16452	Ao			8·76	8·63	+0·13	8·78	8·60	8·7		8·09	8·64	+0·05
E8													
18654 A	A3	7·48	6·82	8·06	7·84	+0·22	8·07	7·86	8·1		8·07	7·87	+0·20
18555 B	Ao	7·71	8·00	7·86	8·00	−0·14	7·88	8·04	7·9	7·78	7·86	7·99	−0·13
18657 C	G5	7·75	7·76	7·39	6·43	+0·96	7·41	6·41	7·7	6·58	7·57	6·56	+1·01
18656 D	Fo	7·91	7·75	7·90	7·71	+0·19	7·91	7·72	8·0	7·89	7·93	7·74	+0·19
18557 E	Ko	7·91	6·59	7·78	6·37	+1·41	7·86	6·10	7·8	6·60	7·98	6·50	+1·48
18582 F	A5	8·21	7·98	8·09	7·82	+0·27	8·10	7·81	8·3	7·75	8·11	7·86	+0·25
18592 G	F5	8·55	8·32	8·52	8·03	+0·49	8·52	8·00	8·8	8·06	8·51	8·09	+0·42
18567 H	A2	8·56	8·27	8·52	8·36	+0·16	8·57	8·35	8·3	8·35	8·49	8·38	+0·11

TABLE I—*continued*

Star	Sp.	*Pg*(*H*)	*Pv*(*H*)	*Pg*	*Pv*	*C.I.*	*Pg'*	*Pv'*	*Pg*(*h*)	*HPv*	*IPg*	*IPv*	*C.I.*$_i$
E8 (*cont.*)													
18534 I	Ao	8·77	8·69	8·79	8·82	−0·03	8·75	8·73	8·9		8·69	8·80	−0·11
18619 K	F5	8·91	8·47	8·90	8·46	+0·44	8·85	8·41	8·0	8·39	8·84	8·51	+0·33
18594 L	Ko	9·11	8·02	8·96	7·70	+1·26	8·99	7·65	9·1	7·96	9·00	7·87	+1·13
18637 M	Ko	9·12	8·04	8·99	7·64	+1·35	9·04	7·73	9·0		9·04	7·85	+1·19
18575 N	Ko	9·55	8·38	9·39	8·18	+1·21	9·36	8·10	9·4	8·29	9·36	8·33	+1·03
18605 O	K2	9·60	8·04	9·50	7·86	+1·64	9·42	7·86	9·4	8·17	9·50	8·09	+1·41
18580 P	F5	9·78	9·24	9·78		+0·50	9·72	9·22	10·1		9·62	9·29	+0·33
18633 Q	F5	10·01	9·37	10·05		+0·53	9·92	9·39	10·3		9·84	9·46	+0·38
18630 R	Ko	10·16	9·02			+1·12	9·98	8·86	10·2		9·88	9·02	+0·86
S	Ko	10·63	9·64			+1·11	10·42	9·31		9·40	10·27	9·47	+0·80
f 18984 T	F8	10·67	9·57			+0·65	10·63:	9·98	10·6		10·41:	10·07	+0·34:
U	Ko	10·85	9·51			+0·91	10·72	9·81			10·52	9·94	+0·58
18508	F8			7·90	7·42	+0·48	7·87	7·44	7·9		7·95	7·49	+0·46
18536	F2			8·06	7·61	+0·45	8·05	7·69	8·3		8·10	7·69	+0·41
18565	F2			7·88	7·57	+0·31	7·89	7·64	8·1		7·92	7·63	+0·29
18588	Ko			8·44	6·67	+1·77	8·39	6·71	8·2		8·57	6·93	+1·64
18679	Ao			7·74	7·85	−0·11	7·75	7·73	7·8		7·76	7·80	−0·04
18691	A2			8·34	8·21	+0·13	8·35	8·22	8·0		8·31	8·23	+0·08
18719	Fo			7·29	7·07	+0·22	7·30	7·08	7·7	7·17	7·39	7·10	+0·29
18724	Go			7·97	7·39	+0·58	7·97	7·46	7·8		8·03	7·49	+0·54
18726	Ko			8·48	7·36	+1·12	8·46	7·39	8·4	7·48	8·55	7·53	+1·02
18743	Ko			8·69	7·57	+1·12	8·68	7·66	8·3		8·73	7·75	+0·98
18747	F5			7·81	7·29	+0·52	7·76	7·22	8·1		7·88	7·34	+0·54
E9													
20214 A	Ao	7·18	7·33	7·36	7·36	0·00	7·35	7·36	7·0	7·30	7·43	7·36	+0·07
20015 B	F8	7·20	6·97	7·21	6·75	+0·46	7·25	6·81	7·0	6·63	7·36	6·82	+0·54
19984 C	Ko	7·70	7·08	7·68	6·69	+0·99	7·72	6·76	7·3	6·76	7·83	6·85	+0·98
20119 D	Go	7·78	7·29	7·78	7·18	+0·60	7·81	7·16	7·6	7·40	7·88	7·26	+0·62
20202 E	Fo	7·94	7·84	8·04	7·73	+0·31	8·01	7·69	7·9		8·06	7·76	+0·30
20142 F	Ao	8·05	7·96	8·10	8·14	−0·04	8·09	8·17	7·9	8·04	8·09	8·14	−0·05
20114 G	F2	8·55	8·41:	8·60	8·27	+0·33	8·61	8·26	8·4		8·57	8·32	+0·25
20053 H	F5	8·56	8·40	8·62	8·11	+0·51	8·58	8·26	8·5		8·60	8·22	+0·38
20134 I	Go	9·14	8·60	9·13	8·46	+0·67	9·16	8·48	8·9		9·08	8·55	+0·53
20054 K	Fo	9·15	9·05	9·25	9·00	+0·25	9·21	9·02	8·8	8·99	9·13	9·04	+0·09
20039 L	A5	9·23	9·07	9·30	9·01	+0·29	9·29	8·88	9·0		9·19	9·02	+0·17
20080 M	F2	9·47	9·26	9·68		+0·41	9·62	9·21	9·4		9·52	9·27	+0·25
20112 N	A2	9·56	9·36	9·61		+0·27	9·59	9·32	9·3	9·34	9·45	9·36	+0·09
20116 O	K2	9·62	8·87	9·69	8·55	+1·14	9·73	8·54	9·4		9·65	8·71	+0·94
20127 P	Ko	9·94	9·11	9·98:	8·73	+1·25:	9·95	8·73	9·8	8·78	9·88	8·91	+0·97
20104 Q	G5	10·17	9·42			+1·12	10·17	9·05	10·2		10·05	9·21	+0·84
20076 R	G5	10·67				+1·47	10·66	9·19	10·9		10·53	9·40	+1·13
f 20079 S	K2	10·78	9·33			+1·65	10·87	9·22	11·0	9·61	10·73	9·45	+1·28
f 20072 T	Go	10·83				+0·77	10·91	10·14	11·0		10·67	10·25	+0·42
f 20057 U	G5	11·18				+0·68	11·24	10·56	11·4		10·95	10·66	+0·29
V		11·38				+1·10	11·31	10·21			11·07	10·36	+0·71
W		11·49				+2·06	11·39	9·33			11·25	9·62	+1·63
20070	Ko			7·00	5·94	+1·06	7·03	5·97	7·0	6·13	7·24	6·10	+1·14
20098	F5			8·40	8·01	+0·39	8·36	8·07	8·1		8·39	8·07	+0·32
20118	Go			9·37	8·84	+0·53	9·41	8·79	9·0		9·29	8·90	+0·39
20129	G5			8·03	6·94	+1·09	8·05	6·95	7·5		8·15	7·09	+1·06
20160	Ko			8·68	6·98	+1·70	8·68	6·97	8·2		8·80	7·22	+1·58
20167	Ko			7·95	6·70	+1·25	7·99	6·67	7·7		8·10	6·87	+1·23
20175	Go			8·86	8·26	+0·60	8·87	8·24	8·6		8·84	8·34	+0·50
20185	F8			8·96	8·45	+0·51	8·97	8·44	8·8		8·91	8·52	+0·39
20186	F2			7·86	7·54	+0·32	7·84	7·50	7·8		7·92	7·57	+0·35

Explanation and Notes

The first column gives the number of the star in the Cape Zone Catalogues, an f in front denoting that this number is from the second or faint star catalogue. The letter following the number gives the star's designation in the corresponding Harvard sequence. The second column gives the Harvard spectral type, while the third and fourth columns give the photographic and photovisual magnitudes according to *H.A.*, 89. The fifth, sixth and seventh columns give the magnitudes and corresponding colour indices as found from the intercomparison plates; columns eight and nine those found from plates taken with a diffraction grating. Column ten gives the photographic magnitude according to the Cape Zone Catalogues, while column eleven gives the photovisual magnitude according to the Harvard Mimeograms 1 and 2 of Series III. The last three columns give the magnitudes and colour indices on what is hoped is the international system. They were derived from the *Pg*, *Pv*, *Pg'* and *Pv'* magnitudes by the formulæ found in this paper. About three times more weight was given to the *Pg* and *Pv* magnitudes than to the *Pg'* and *Pv'* magnitudes.

The *HPv* magnitude of B of E1 should probably be altered by one magnitude.

B of E3 and B of E6 are double stars, the components of which are too close on our plates to be measured separately, but not close enough to be treated as a single star.

The Harvard magnitudes for stars A and C of E8 should perhaps be interchanged, as the stars being close together may have been misidentified.

TABLE II

Observed and Computed Differential Atmospheric Extinction

(Units $0^m.01$)

Mean x / Hour Angle		−63	−45	−27	−9	+9	+27	+45	+63
				Photographic					
h m									
4 00	Observed	−4·6	−2·8	+0·4	−0·4	0·0	+0·8	+3·4	+1·9
	Computed	−4·6	−3·3	−2·0	−0·7	+0·7	+2·0	+3·3	+4·6
2 40	Observed	−4·1	+0·8	−0·3	−0·9	−0·6	+1·5	+1·3	+2·9
	Computed	−2·1	−1·5	−0·9	−0·3	+0·3	+0·9	+1·5	+2·1
1 20	Observed	+1·5	−0·5	−0·4	−1·3	−0·7	+0·9	+2·0	+1·9
	Computed	−1·1	−0·8	−0·5	−0·2	+0·2	+0·5	+0·8	+1·1
				Photovisual					
4 00	Observed	−4·7	−2·6	−0·8	−0·3	+0·5	+2·9	−0·4	+2·9
	Computed	−2·8	−2·0	−1·2	−0·4	+0·4	+1·2	+2·0	+2·8
2 40	Observed	+3·2	+2·1	−1·0	−0·7	+0·5	+0·4	−0·7	−2·1
	Computed	−1·4	−1·0	−0·6	−0·2	+0·2	+0·6	+1·0	+1·4
1 20	Observed	−1·0	+0·6	+0·9	+0·2	−0·1	+0·8	−1·2	−1·6
	Computed	−0·7	−0·5	−0·3	−0·1	+0·1	+0·3	+0·5	+0·7

be noticed from Table III (which gives the mean zero point residuals arranged according to hour angle) that for the photographic plates there is a small but distinct run in these residuals. The possibility of this being a differential extinction effect depending on the centroid of the observed stars not coinciding with the geometric centre of the plate has been examined and rejected since the centroid of the stars measured lies on the average about $0°.1$ east and about $0°.01$ south of the centre of the plate. Nor could an explanation be found in the order in which the comparison plates were taken or measured, as it was found that the number of plates on which the regions were observed in the order W–E–W was about equal to the number in which they were observed in the

order E–W–E. The run of the effect suggests that it varies with zenith distance. It may be due to a small difference between the extinction in the eastern and western part of the Cape sky, or, what is perhaps equivalent, a systematic difference in the quality of the seeing. In any case the effect is too small to be of much importance until the accuracy of the normal photometric observations is enormously increased.

TABLE III

Mean Zero Point Residuals Arranged according to Hour Angle

(Units $0^m.01$)

H.A.	East			West		
	$4^h\ 00^m$	$2^h\ 40^m$	$1^h\ 20^m$	$1^h\ 20^m$	$2^h\ 40^m$	$4^h\ 00^m$
Photographic	+1·3	+0·7	+0·1	0·0	−0·7	−1·7
Photovisual	0·0	+0·2	−0·2	+0·1	+0·2	−0·7

The residuals were also examined for a differential extinction effect depending on the colour of the individual star. The sums of the residuals for the plates taken 4^h off the meridian were arranged in classes according to the colour index of the corresponding stars, or rather according to the difference of this colour index from the mean colour index for the particular region. The residuals for the plates taken $1^h\ 20^m$ off the meridian were treated similarly. The difference between the results divided by two is shown in Table IV. The corresponding difference between the secants of the zenith

TABLE IV

Differences in Atmospheric Extinction Depending on the Colour of the Stars

(Units $0^m.01$; $\Delta \sec z = 0.4$)

Δ C.I.	< -0.6	-0.6 to -0.3	-0.3 to 0	0 to $+0.3$	$+0.3$ to $+0.9$	$> +0.9$
Photographic	+1·3	+1·5	+0·7	−1·8	−2·4	−1·8
Photovisual	+1·3	−0·5	−1·4	−0·3	0·0	+1·7

distances is 0·396. The m^{iv} magnitudes are those that would be observed at the zenith distance of about 36°, to obtain those as observed at the zenith a small correction depending on colour will have to be applied. Assuming that the selective extinction bears a constant relation to the total extinction, this correction will amount to about half of the quantity shown in Table IV. This correction has been ignored. It must be noted, however, that at large zenith distances this correction will be appreciable, for example at a zenith distance of 60° it may well amount to five or six hundredths of a magnitude.

The dependence of the size of the residuals on the position of the star on the plate was also examined, but no appreciable effect was found. This examination was only cursory and made rather as a precaution than as an attempt to evaluate the distance corrections, a purpose for which this material is not suited. It is planned to evaluate these corrections, with the help of the material available from the overlapping plates of the $-30°$ to $-35°$ zone. It is hoped that this correction will prove to be small as only the central $5° \times 5°$ of the field of a lens designed to cover $15° \times 15°$ has been used.

The Magnitudes from the Grating Plates.—The individual m^{iv} magnitudes depend only on the forty-odd pairs of plates used for intercomparing the E regions, but the way in which they were derived *via* the m^{iii} system from the m^{ii} system should ensure that they have the same mean scale and zero point as the Harvard magnitudes. In order to extend the range of magnitudes available for comparison with other systems, the two grating plates of each region were reduced with the aid of the m^{iv} magnitudes in the same way as the grating plates of the −30° to −35° zone are being reduced by means of the stars whose magnitudes have been found from direct comparison with the m^{iv} magnitudes. The differences between the tabulated magnitudes and the m^{iv} magnitudes are plotted against the tabular magnitude, the scale used for the former being fifty times that used for the latter. The resulting reduction curves for the central and side images which are treated separately are parallel and, as they cover different ranges of m_{Tab}, can be used to extend each other. The distance between the curves, which is found from the overlap, is the value of the grating constant. The value of this constant is not assumed to be known. Each plate is reduced with the value of the constant found from the reduction curves for the plate itself.

The magnitudes resulting from the reduction of these grating plates are entered in Table I under the headings of *Pg′* and *Pv′*. Individually they are independent of the m^{iv} (or *Pg*, *Pv* magnitudes), being found from different material, but the two sets of magnitudes have been made to agree as to scale and zero point region by region. The probable error of *Pg′* as found from the agreement between the two grating plates is about ±0^m.020 for the brighter stars showing side images and about ±0^m.032 for the fainter stars, whose magnitudes for the most part are extrapolations beyond the range covered by the m^{iv} series. The corresponding probable errors for *Pv′* are ±0^m.023 and ±0^m.041. The average difference between the individual *Pg* and *Pg′* magnitudes is 0^m.034 and that between *Pv* and *Pv′* 0^m.039. These differences are but little greater than those to be expected from the size of the probable errors of *Pg*, *Pv*, *Pg′*, *Pv′* deduced from the internal agreements and given above.

Variation of the Grating Constant with Spectral Type.—To test for variations in the grating constant with spectral type, the magnitudes as found from the side images were compared with those found from the central images. When the differences between these magnitudes were arranged according to the spectral type of the stars no definite relation emerged, though there were indications that these differences varied with the spectral type within each region. The differences were therefore re-arranged according to the difference of the colour index of the star from the mean colour index of the stars in the particular region that the star happens to be. The relations resulting from this arrangement are shown in Table V.

TABLE V

$m_{central} - m_{side}$ *in Units of* 0^m.01

Δ C.I.	< −0·6	−0·6 to −0·3	−0·3 to 0	0 to +0·3	+0·3 to +0·9	> +0·9
			Photographic			
No. of stars	14	52	36	19	24	11
Mean $m_c - m_s$	−3·7	−1·9	+0·7	+3·8	+5·4	+11·5
			Photovisual			
No. of stars	12	44	26	16	20	13
Mean $m_c - m_s$	+0·3	+2·3	+1·5	+2·3	+0·3	− 4·5

(Each star is on both plates, so number of differences is twice number of stars.)

The marked run of $m_c - m_s$ with colour in the case of the photographic plates means that there will be a certain amount of ambiguity in the scale of magnitudes derived by means of the grating. According to Table V this ambiguity may amount to about $0^m.07$ per magnitude difference between the scale for extremely red and for extremely blue stars. As it does not seem possible to assign to any specified colour a definite grating constant, there seems no easy way in which to eliminate this colour effect. If this effect is due to structural peculiarities arising from the closeness of the side and central images it would not be serious, as it would largely disappear from the final magnitude which is the mean of the magnitudes derived from the central and side images. If, on the other hand, it has its origin in intrinsic properties of the photographic plate such as the change in contrast with wave-length, or in the way in which images of different colour build up with increasing exposure (which of course will depend also partly on the camera), the effect is likely to be important and will need further consideration.

To fix our ideas, let us take an idealised case (suggested by Table V) in which the photographic magnitudes are subject to a linear effect while the photovisual ones are unaffected. Suppose $C.I._0$ denotes the colour index of stars for which the derived scale of photographic magnitudes is normal, then the photographic scale as determined by the grating for stars whose colour index (on a normal scale) is $C.I.$ will differ from the normal scale by an amount $p(C.I. - C.I._0)$ per magnitude. That is, the observed photographic magnitude will need a correction of $p(m_{pg} - m_{pg}')(C.I. - C.I._0)$, where m_{pg}' denotes the magnitude at which, by the application of a zero correction, or otherwise, the apparent photographic scale has been made to coincide with the normal scale. The observed colour indices will need a similar correction.

In passing it is interesting to note that Bergstrand * when examining the differences between photographic magnitudes determined at Greenwich and Upsala found he had to include a term $-0.079(m-9)C.I.$ The Upsala magnitudes were determined with the aid of a grating, while the Greenwich ones were obtained by direct comparison with the polar sequence.

It seemed worth while to see if the colour indices for stars of a given spectral type showed any change with apparent magnitude. The colour indices of the stars in the E regions, being insufficient for this purpose, were supplemented by those for the first 5000 stars of the $-30°$ to $-35°$ zone whose magnitudes had been reduced to the same system. The final corrections for position on plate, etc. have not been applied to these stars, but these corrections are not likely to be large nor to produce any systematic effect on the colour indices. The spectral types for just over 3000 of these stars are given in the Henry Draper Catalogue. The result of the analysis is shown in Table VI.

For the later types the colour indices of the giants and dwarfs have not been separated, so that part of the change of colour index with magnitude will be due to their varying proportion. On the other hand, the effect of the larger colour indices of the giants is partly compensated for by the presence of stars with colour indices much below normal, such stars, for example, as 726 in E1 or C in E9. Whether these low colour indices are real or the result of mistaken spectral classification or other observational shortcomings is immaterial for this purpose of serving as a counterbalancing effect to the giants. A more important complicating effect for the stars of large colour index will be due to the incompleteness of the photographic magnitudes and of the spectral classification. For example a K0 star of photovisual magnitude 10 and colour index 1.00 will occur, for its photographic magnitude will have been measured, but if its colour index were 1.50 it is quite likely that either its photographic magnitude was not measured or that its spectrum was too faint to appear in the Draper Catalogue.

Table VI shows that some such effect as was predicted from the change in grating constant is present, $C.I._0$ being about 0.4 or 0.5. Taking m_{pg}' as 8.5 (8.0 photovisual) the value of p would, at first sight, appear to be about 0.14, though the slopes for the

* *Ups. Med.*, 59, 24, 1934.

various spectral types do not vary quite as $C.I. - C.I._0$. The colour indices may also show a change with magnitude on account of the photographic and photovisual magnitude scales not being quite the same, an effect which would be independent of spectral type. Nor can the possibility that there is also a real change with magnitude be completely ruled out. For these reasons this evaluation of p obtained from the variation of the colour indices cannot be taken very seriously, but the knowledge that this effect is there

TABLE VI

Variation of Colour Index with the Measured Photovisual Magnitude

(Number of stars in parentheses)

Sp. Type \ *Pv'*	6·5	7·0	7·5	8·0	8·5	9·0	9·5	10·0
B3	− ·25(1)	− ·30(2)	− ·25(5)	− ·28(2)	(0)	− ·31(1)	− ·10(1)	(0)
B5	− ·26(2)	− ·34(3)	− ·01(2)	− ·20(6)	− ·07(1)	− ·04(3)	(0)	+ ·19(1)
B8	(0)	− ·24(4)	− ·22(7)	− ·18(12)	− ·07(14)	− ·03(14)	+ ·03(5)	+ ·25(1)
B9	− ·28(4)	− ·17(7)	− ·12(8)	− ·12(28)	− ·09(21)	+ ·01(28)	+ ·01(10)	+ ·19(1)
A0	− ·15(5)	− ·07(12)	− ·11(26)	− ·01(51)	+ ·07(67)	+ ·13(102)	+ ·11(66)	+ ·10(20)
A2	− ·10(2)	00(7)	00(12)	+ ·13(35)	+ ·13(49)	+ ·22(37)	+ ·22(33)	+ ·22(11)
A3	+ ·14(4)	+ ·13(5)	+ ·07(5)	+ ·20(9)	+ ·26(18)	+ ·29(19)	+ ·33(16)	+ ·21(3)
A5	+ ·22(2)	+ ·15(3)	+ ·16(4)	+ ·22(9)	+ ·28(13)	+ ·36(25)	+ ·32(19)	+ ·28(7)
F0	+ ·22(5)	+ ·29(8)	+ ·27(16)	+ ·29(23)	+ ·35(34)	+ ·39(44)	+ ·38(18)	+ ·25(2)
F2	+ ·34(2)	+ ·42(5)	+ ·37(9)	+ ·40(14)	+ ·43(27)	+ ·42(34)	+ ·42(24)	+ ·18(1)
F5	+ ·41(11)	+ ·43(7)	+ ·43(12)	+ ·45(27)	+ ·47(43)	+ ·53(70)	+ ·47(36)	+ ·43(7)
F8	+ ·39(2)	+ ·47(6)	+ ·56(6)	+ ·52(18)	+ ·59(37)	+ ·49(61)	+ ·63(46)	+ ·46(18)
G0	+ ·83(6)	+ ·62(8)	+ ·65(13)	+ ·67(31)	+ ·70(56)	+ ·64(98)	+ ·58(111)	+ ·55(30)
G5	+1·05(19)	+1·08(33)	+1·05(35)	+ ·97(47)	+ ·96(84)	+ ·95(128)	+ ·82(68)	+ ·74(12)
K0	+1·34(39)	+1·34(39)	+1·25(65)	+1·24(101)	+1·21(128)	+1·15(124)	+1·13(43)	+ ·99(6)
K2	+1·61(8)	+1·56(15)	+1·51(22)	+1·43(44)	+1·38(64)	+1·33(55)	+1·21(11)	(0)
K5	+1·76(7)	+1·80(6)	+1·72(28)	+1·68(30)	+1·57(55)	+1·40(33)	+1·22(7)	(0)
Ma	+1·90(3)	+1·85(3)	+1·75(8)	+2·00(4)	+1·77(7)	+1·76(1)	(0)	+1·53(1)

must be constantly borne in mind, especially when intercomparing different scales of magnitudes and in statistical work.

Intercomparison with other magnitudes determined in an entirely different way is likely to be the best way of evaluating p.

Other Photographic Magnitudes.—There are two series of photographic magnitudes with which the *Pg* and *Pg'* systems can be directly compared. These are the Harvard photographic magnitudes given in Table I under the heading *Pg(H)* and the Cape Zone magnitudes given under the heading *Pg(h)*.

The original source of the Harvard magnitudes is Part 4 of *H.A.*, **71**, 1917, but the magnitudes given there have been reduced to the 1922 system by means of the corrections given in *H.B.*, 781, 1923. These magnitudes depend mainly on plates taken with the 8-inch Bache telescope, though plates taken with three 1-inch Cooke lenses and with the 24-inch Bruce telescope were also used. No corrections were applied for the colour equations of the various instruments, nor for any other systematic differences among them. The scale and zero point was transferred from the C regions at +15° declination by the usual Harvard method. Twelve plates from a single box were exposed in succession, the first, sixth and last being on one of the C regions, the intermediate ones on the E regions or other areas in which magnitudes were required. All the exposures were of the same length and the twelve plates were developed together. The plates

were exposed as near to the meridian as possible, the differences in zenith distances being allowed for by corrections based on a mean atmospheric absorption coefficient. The magnitudes in the C regions were themselves obtained from the north polar sequence in a similar manner. On an average there were 13 plates available for each E region, but of these 13 only an average of 4 were "series" plates. The probable error of an individual star in the E regions is given as $\pm 0^m.093$ or as about $\pm 0^m.06$ if all systematic errors are eliminated. The mean zero error for the sequence of magnitudes in an individual region is given as $\pm 0^m.08$. Some of Miss Leavitt's comments * are worth quoting.

> ". . . it should be noticed that the probable errors are smallest for the E and F regions, which depend principally on three classes of images, namely, primary images, prismatic companions, and diffraction images on Bache plates. . . . In the A, B, and C regions the average number of groups in which any star was measured, the variety of instruments employed, and the probable errors, all are larger than for the other regions. The inevitable conclusion is that the computed probable error increases with the number of instruments. Although, however, the most accordant results are to be obtained with a single class of images, great caution should evidently be used in accepting as final the results from one or two instruments, even if they agree well with each other. It is believed that the systematic errors depending on the various classes of images included in the results here given largely counterbalance one another, especially for the regions north of the Equator. The scale for the E and F regions is much less certainly established, notwithstanding their smaller probable errors."

The derivation of the Cape Zone magnitudes is explained in the introduction to *Magnitudes of Stars contained in the Cape Zone Catalogue of 20,843 Stars* (London, 1927), and the magnitudes of the brighter stars are given in that catalogue, while those for the fainter stars are given in the *Catalogue of 20,554 Faint Stars in the Cape Astrographic Zone* (London, 1939). These magnitudes are simply the converted diameter measures of the Cape Astrographic and C.P.D. catalogues. A single diameter-magnitude relation was used throughout, but the magnitudes were adjusted for zero point, plate by plate, by means of stars whose Harvard visual magnitudes and spectral types were known. The diameter-magnitude relation used was the combination of three, each determined in a different way. Two of these ways depended on the application of Kron's law of photographic action, and the other on the Harvard visual magnitudes corrected for spectral type. Each catalogue magnitude is the mean of at least three diameter measures, two of these being on astrographic plates and the third on a C.P.D. plate. The probable error of a single catalogue magnitude is given as $\pm 0^m.13$ and the probable error of the zero point as $\pm 0^m.08$.

In his introduction to the Cape magnitudes, Dr. Halm compared the Cape Zone magnitudes for the brighter stars with the Harvard magnitudes as printed in *H.A.*, **71**. He found the relation between the two sets of magnitudes to be

$$\text{Cape} - \text{Harvard} = -0.10 + 0.07(m - 6).$$

If the 1922 corrections be applied to the Harvard magnitudes, the scale difference is completely removed and this relation becomes

$$\text{Cape} - \text{Harvard (Cor.)} = +0.02.$$

An indirect comparison between the Harvard and Cape magnitudes can be made by means of the photographic magnitudes of about 17,800 stars in the Kapteyn Selected Areas at $-45°$, which were published by Harvard in 1935. These magnitudes were

* *H.A.*, 71, 314, 1917.

determined in the same way as those for the E regions from plates taken with the 8-inch Bache telescope and standardised on the C regions. About four plates were used for each area. The magnitudes of about 1800 of these stars are given in the first (bright star) Cape Zone Catalogue and the magnitudes for a further 2200 in the second (faint star) Cape Zone Catalogue. The relations between the two sets of magnitudes have been examined by the Gaposchkins * for the bright stars and by Jackson † for the faint ones. In both cases the outstanding feature of the comparisons are the zero point differences from area to area. These differences are not always the same for the bright and faint stars and indicate irregular scale changes from area to area. Treating all the areas together, the Gaposchkins found

$$\text{Harvard S.A.} - \text{Cape} = -0{\cdot}04(\text{Cape} - 9{\cdot}3) - 0{\cdot}07,$$

together with the possibility of a small colour coefficient of 0·02. They were inclined to attribute part of the large zone differences to systematic effects depending on galactic latitude and on right ascension, but, as Jackson has pointed out, the evidence for doing this is not convincing. Ignoring these systematic effects and also presumably the zero errors of the Harvard magnitudes, they find $\pm 0^{m}{\cdot}14$ as the probable error to be assigned to the zero point of the Cape magnitudes in a single area—considerably larger than the $\pm 0^{m}{\cdot}08$ given by Halm.

Intercomparison of the Photographic Magnitude Systems.—The results of comparing the present system of photographic magnitudes of Harvard and with that of the Cape Zones are shown in Tables VII to XIII. These comparisons were carried out as follows.

TABLE VII *

$Pg' - Pg$

Pg	7·0	7·5	8·0	8·5	9·0	9·5	10·0	10·5	11·0
C.I. < ·20	+·01(5)	+·01(14)	·00(25)	−·01(18)	−·03(4)	−·03(5)	−·15(1)		
·20 < *C.I.* < ·80	+·02(9)	+·01(4)	·00(14)	·00(17)	·00(28)	·00(16)	−·08(9)		
C.I. > ·80	+·01(2)	·00(9)	+·01(9)	−·01(10)	+·03(10)	·00(9)	−·03(5)		
All stars	+·02(16)	+·01(27)	·00(48)	−·01(45)	·00(42)	−·01(30)	−·07(15)		

C.I.	−·20	·00	+·20	+·38	+·52	+·70	+·95	+1·25	+1·60
Pg < 8·5	·00(20)	·00(25)	·00(14)	−·01(13)	+·01(9)	+·03(2)	+·02(9)	·00(10)	·00(5)
Pg > 8·5	+·02(1)	−·03(13)	−·02(24)	−·01(15)	−·02(18)	−·01(14)	−·01(9)	+ ·01(13)	− ·01(8)
All stars	·00(21)	−·01(38)	−·01(38)	−·01(28)	·00(27)	−·01(16)	·00(18)	·00(23)	·00(13)

Mean arithmetical difference $Pg' - Pg = 0^{m}{\cdot}034$.

The differences between the individual magnitudes were examined region by region and approximate zero point differences removed.

The differences between the individual magnitudes thus corrected were then arranged according to magnitude and according to colour. For the arrangements according to magnitude, the material was divided into three subgroups, the first containing all stars whose Cape colour index was less than 0·20, the second all stars for

* *H.B.*, 901, 25, 1935.

† *Catalogue of 20,554 Faint Stars in the Cape Astrographic Zone*, vi, 1939.

‡ In this and subsequent tables the number of stars on which the mean depends is given in parentheses.

which this colour index lay between 0·20 and 0·80 and the third all stars for which the colour index exceeded 0·80. For the arrangements of the differences according to colour the material was divided into two subgroups only, the first containing the brighter stars, the second the fainter ones. It will be noticed that there is a marked correlation between

TABLE VIII

Pg(H) − Pg′ (all stars)

Pg′	7·0	7·5	8·0	8·5	9·0	9·5	10·0	10·5	11·0
C.I. < ·20	+·05(4)	−·10(10)	−·03(15)	−·03(7)	−·06(4)	−·05(4)	+·04(2)	+ ·13(1)	+ ·02(1)
·20 < *C.I.* < ·80	+·12(5)	−·02(3)	−·04(5)	+·05(10)	−·04(15)	−·04(13)	+·01(14)	− ·00(8)	− ·11(5)
C.I. > ·80	+·37(1)	+·09(4)	−·02(6)	+·03(2)	+·06(5)	+·08(8)	+·02(10)	+ ·09(10)	+ ·02(12)
All stars	+·11(10)	−·04(17)	−·03(26)	+·02(19)	+·02(24)	·00(25)	+·01(26)	+ ·05(19)	− ·02(18)

C.I.	−·20	·00	+·20	+·38	+·52	+·70	+·95	+1·25	+1·60
Pg < 8·5	−·08(16)	−·02(18)	−·03(7)	+·02(10)	+·06(11)	+·02(4)	+·07(4)	+ ·05(8)	+ ·10(3)
Pg > 8·5	+·17(1)	−·06(6)	−·04(21)	−·07(14)	+·02(8)	−·01(12)	+·09(8)	+ ·04(17)	+ ·05(12)
All stars	−·06(17)	−·03(24)	−·04(28)	−·03(24)	+·04(19)	·00(16)	+·08(12)	+ ·04(25)	+ ·06(15)

Mean arithmetical difference $Ph(H) - Pg' = 0^{m}\cdot087$.

TABLE IX

Pg(H) − Pg′ (large residuals omitted)

Pg′	7·0	7·5	8·0	8·5	9·0	9·5	10·0	10·5	11·0
C.I. < ·20	−·03(3)	−·05(8)	−·02(13)	−·03(7)	−·06(4)	·00(3)	+·04(2)	+ ·13(1)	+ ·02(1)
·20 < *C.I.* < ·80	+·01(3)	−·02(3)	+·04(5)	·00(8)	−·02(14)	−·04(13)	−·01(12)	+ ·03(7)	− ·06(4)
C.I. > ·80	(0)	+·05(3)	−·02(6)	+·03(2)	+·06(5)	+·08(8)	+·02(10)	+ ·07(9)	+ ·02(10)
All stars	−·01(6)	−·02(14)	−·01(24)	−·01(17)	−·01(23)	·00(24)	+·01(24)	+ ·06(17)	·00(15)

C.I.	−·20	·00	+·20	+·38	+·52	+·70	+·95	+1·25	+1·60
Pg < 8·5	−·04(13)	−·02(16)	−·07(6)	+·03(8)	·00(9)	+·02(4)	−·04(3)	+ ·03(7)	+ ·10(3)
Pg > 8·5	+·17(1)	−·03(5)	−·03(20)	−·03(12)	·00(7)	+·01(11)	+·05(6)	+ ·04(17)	+ ·05(12)
All stars	−·03(14)	−·02(21)	−·04(26)	−·01(20)	·00(16)	+·01(15)	+·02(9)	+ ·04(24)	+ ·06(15)
·06 (*C.I.* − ·6)	−·05	−·04	−·02	−·01	·00	+·01	+·02	+ ·04	+ ·06

Mean arithmetical difference $Pg(H) - Pg' = 0^{m}\cdot069$.

the brightness and colour of the stars in the E region sequences, the brighter stars being bluer than the average, the fainter stars redder. Because of this, the scale and colour relations found from this material will be interlocked and if there is either an appreciable scale or colour difference between the systems of magnitudes being compared, the corresponding colour or scale relation found in the manner described will need small corrections. Such corrections are applied in Tables X and XI.

As a matter of precaution and as a basis of comparison, the *Pg* and *Pg′* systems were first compared. There appears to be no appreciable difference between them for magnitudes brighter than 9·5, but for magnitudes fainter than this, the *Pg′* magnitudes are systematically the brighter. For this range of magnitude, they are presumably the more reliable. This difference might arise from the way in which the reduction curves used to obtain m^{III} were forced to be straight lines, the effect of this linear reduction being not completely eliminated in the subsequent reduction to the m^{IV} system.

The Harvard magnitudes were then compared with the *Pg′* ones. With the zero point differences approximately removed the average arithmetical difference between the *pg*(*H*) and *Pg′* magnitudes was $0^m.087$. When 20 large differences exceeding $0^m.20$ were dropped the average arithmetical difference of the remaining 160-odd was reduced to $0^m.069$. Two comparisons were made, one including these 20 stars, the other excluding them. The results are substantially the same, though those for the former are naturally rather more ragged and the implied colour difference rather larger. For all the regions taken together, there appears to be no appreciable scale difference between the two systems of magnitudes. There is, however, a fairly well-defined colour difference that can be represented by

$$Pg(H) - Pg' = 0{\cdot}06(C.I. - 0{\cdot}6).$$

There are some indications of small systematic differences between the red and blue stars, but the data are not sufficiently extensive nor sufficiently accurate to justify their

TABLE X

Pg(*h*) − *Pg′*

Pg′	7·0	7·5	8·0	8·5	9·0	9·5	10·0	10·5	11·0
C.I. < ·20	+·22(6)	+·14(14)	+·08(24)	+·04(18)	+·02(6)	+·04(5)	+·20(4)	+ ·30(1)	+ ·10(1)
·20 < *C.I.* < ·80	+·06(7)	+·26(5)	+·11(13)	+·02(17)	−·11(28)	−·10(15)	−·05(11)	+ ·02(5)	+ ·20(4)
C.I. > ·80	+·35(2)	+·05(6)	−·12(11)	−·24(10)	−·12(11)	−·04(9)	+·17(10)	+ ·12(4)	+ ·05(2)
All stars	+·16(15)	+·14(25)	+·04(48)	−·03(45)	−·09(45)	−·06(29)	+·08(25)	+ ·09(10)	+ ·14(7)

C.I.	−·20	·00	+·20	+·38	+·52	+·70	+·95	+1·25	+1·60
				Pg′ < 8·6					
Pg(*h*) − *Pg′*	+·13(19)	+·13(26)	+·03(17)	+·11(10)	+·06(14)	+·12(4)	+·01(9)	− ·01(9)	− ·21(7)
Pg′	7·7	7·9	8·0	7·9	7·9	7·7	7·8	7·9	8·4
Scale	+·10	+·06	+·04	+·06	+·06	+·10	+·08	+ ·06	− ·02
Colour	+·03	+·07	−·01	+·05	·00	+·02	−·07	− ·07	− ·19
				Pg′ > 8·6					
Pg(*h*) − *Pg′*	+·40(1)	+·03(14)	−·03(24)	−·04(20)	−·10(15)	−·02(21)	+·03(10)	− ·03(18)	·00(11)
Pg′	10·1	9·1	9·6	9·3	9·3	9·6	9·5	9·6	9·7
Scale	+·08	−·08	−·03	−·07	−·07	−·03	−·06	− ·03	·00
Colour	+·32	+·11	·00	+·03	−·03	+·01	+·09	·00	·00
				All stars					
Pg(*h*) − *Pg′*	+·15(20)	+·09(40)	00(41)	+·01(39)	−·02(29)	·00(25)	+·02(19)	− ·03(27)	− ·08(18)
Scale	+·10	+·01	·00	−·03	−·01	−·01	+·01	·00	− ·01
Colour	+·05	+·08	·00	+·04	−·01	+·01	+·01	− ·03	− ·07
−·06 (*C.I.* − ·8)	+·06	+·05	+·04	+·02	+·02	·00	−·01	− ·03	− ·05

Mean arithmetical difference *Pg*(*h*) − *Pg′* = $0^m.17$.

evaluation. For some of the individual regions there are well-defined differences of scale between the two systems of magnitudes, a fact that has to be borne in mind when evaluating the difference in their zero points.

In all comparisons involving Harvard magnitudes, stars A and C of E8 have been omitted. These stars, though completely separate, are fairly close together and appear to have got confused with one another.

The next comparison to be made was that between the Cape Zone magnitudes $Pg(h)$ and the Pg' ones. As $Pg(h)$ magnitudes are given to tenths of magnitudes only, this comparison was made in terms of $0^m.1$ as unit. The average arithmetical difference $Pg(h) - Pg'$ was $0^m.17$, and though the data were much rougher than that for the previous comparison, more stars were available. None of the stars was rejected. In the light of Halm's comparison between $Pg(H)$ and $Pg(h)$ quoted above, the scale relation that was actually found between $Pg(h)$ and Pg' came as a surprise. For all stars taken together it might be represented by

$$\begin{aligned} Pg(h) - Pg' &= -0.14(m - 8.35) \qquad 7 < m < 9 \\ &= +0.12(m - 9.75) \qquad 9 < m < 11. \end{aligned}$$

The colour relation when corrected for these scale runs gives

$$Pg(h) - Pg' = -0.06(C.I. - 0.8).$$

As in the case of $Pg(H) - Pg'$, there are possibilities of small differences between red and blue stars.

TABLE XI

$Pg(h) - Pg(H)$

$Pg(H)$	7·0	7·5	8·0	8·5	9·0	9·5	10·0	10·5	11·0
$C.I. < .20$	+·12(4)	+·17(12)	+·12(8)	+·04(8)	−·10(4)	+·03(4)	+·10(1)	+ ·20(2)	+ ·10(1
$.20 < C.I. < .80$	−·15(6)	+·07(3)	·00(5)	+·06(12)	−·15(12)	−·05(14)	+·04(11)	+ ·02(6)	+ ·30(2
$C.I. > .80$	+·10(1)	−·09(7)	−·05(6)	+·05(4)	−·28(5)	−·06(8)	+·03(11)	+ ·13(4)	− ·20(2
All stars	−·03(11)	+·07(22)	+·04(19)	+·05(24)	−·17(21)	−·04(26)	+·03(23)	+ ·08(12)	+ ·06(5

$C.I.$	−·20	·0	+·20	+·38	+·52	+·70	+·95	+1·25	+1·60
				$Pg(H) < 9.0$					
$Pg(h) - Pg(H)$	+·18(16)	+·04(17)	+·04(8)	−·02(13)	−·07(11)	·00(4)	·00(4)	− ·19(7)	− ·10(4
$Pg(H)$	7·5	8·2	8·1	8·1	8·0	8·7	7·6	7·9	8·4
Scale	+·04	+·04	+·04	+·04	+·04	−·04	+·04	+ ·04	+ ·04
Colour	+·14	·00	·00	−·06	−·11	+·04	−·04	− ·23	− ·14
				$Pg(H) > 9.0$					
$Pg(h) - Pg(H)$	+·10(1)	+·02(5)	+·01(20)	−·01(7)	−·03(6)	+·01(10)	−·06(5)	− ·02(13)	− ·02(9
$Pg(H)$	10·5	9·8	9·8	9·7	10·0	10·1	10·1	9·8	10·0
Scale	+·08	·00	·00	−·01	+·03	+·04	+·04	·00	+ ·03
Colour	+·02	+·02	+·01	·00	−·06	−·03	−·10	− ·02	− ·05
				All Stars					
$Pg(h) - Pg(H)$	+·17(17)	+·04(22)	+·02(28)	−·02(20)	−·06(17)	+·01(14)	−·03(9)	− ·08(20)	− ·05(1
Scale	+·04	+·03	+·01	+·02	+·04	+·02	+·04	+ ·02	+ ·03
Colour	+·13	+·01	+·01	−·04	−·10	−·01	−·07	− ·10	− ·08
$-0.10\ (C.I. - .3)$	+·05	+·03	+·01	−·01	−·02	−·04	−·07	− ·10	− ·13

Mean arithmetical difference $Pg(h) - Pg(H) = 0^m.18$.

In view of the surprising scale relation between $Pg(h)$ and Pg' it was decided to re-examine the relations between $Pg(h)$ and $Pg(H)$. The scale relation found was rather irregular. It might be described as a rather ragged version of that between $Pg(h)$ and Pg', which is what might be expected as there are fewer stars involved in the comparison and the probable errors of the individual differences are slightly larger. The colour relationship between the two sets of magnitudes can be fairly well represented by

$$Pg(h) - Pg(H) = -0{\cdot}10(C.I. - 0{\cdot}3),$$

which checks up fairly well with the relationship to be expected from those found between $Pg(H)$ and Pg' and between $Pg(h)$ and Pg'.

It will be noticed that in spite of the greater red sensitivity of the more modern Ilford Zenith plate, the colour system of the magnitudes found with them appears to be intermediate between those of the Harvard and the Cape Zone magnitudes.

TABLE XII

$Pg(h) - Pg(CSA)$

$Pg(h)$	7·0	7·5	8·0	8·5	9·0	9·5	10·0	10·5	11·0
$Pg(h) - Pg(CSA)$	−·04(25)	+·11(16)	+·09(31)	+·02(45)	−·01(83)	−·10(89)	−·02(99)	+·01(124)	+·11(59)

In an attempt to trace the cause of the discontinuity in the scale relations $Pg(h)$ magnitudes were compared with the magnitudes of stars in the 24 Kapteyn Areas at −45° given in Table A, pp. lxvi to lxxiii of the introduction to *Cape Magnitudes*. These magnitudes, which will be referred to as $Pg(CSA)$, are independent of the $Pg(h)$ magnitudes given in the body of the catalogue. They were obtained by direct comparison with a south polar sequence, the magnitudes in which had been found by means of a diffraction grating and Kron's law of photographic action. (This work formed part of one of the three ways in which the relationship was found between magnitude and diameter on which $Pg(h)$ is based.)

The scale relation between the $Pg(h)$ and $Pg(CSA)$ shows the same abrupt change. There seems little doubt, therefore, that the cause of the discontinuity lies in the $Pg(h)$ magnitudes. This irregularity of the scale may explain part of the discrepancies between the Gaposchkins' comparison and that of Jackson. It must be taken into account when the Cape Zone Catalogues are used for statistical purposes.

The zero point differences between the Pg', $Pg(H)$ and $Pg(h)$ magnitudes are set forth in Table XIII. In order to avoid complications depending on differential scale values in different regions a series of stars common to all three systems were chosen such that their mean Pg' magnitude for any region was about 8·80. The mean colour varied from region to region, but this was allowed for by means of the colour relations that had already been found. The results were reduced to a mean colour of 0·50. There appears to be a systematic difference in zero between $Pg(H)$ and Pg' of $0^m{\cdot}02$; between $Pg(h)$ and Pg' of $0^m{\cdot}05$ and between $Pg(h)$ and $Pg(H)$ of $0^m{\cdot}03$. After these systematic differences have been removed the average arithmetical zero difference per region between $Pg(H)$ and Pg' is $0^m{\cdot}120$, between $Pg(h)$ and Pg' is $0^m{\cdot}111$ and between $Pg(h)$ and $Pg(H)$ is $0^m{\cdot}147$.

If the parts of these differences which are due to the $Pg(H)$, $Pg(h)$ and Pg' magnitudes be denoted by H, h and S respectively, we have

$$H^2 + S^2 = 0{\cdot}0144, \qquad h^2 + S^2 = 0{\cdot}0123, \qquad h^2 + H^2 = 0{\cdot}0216,$$

TABLE XIII

Zero Point Differences between Pg(H), Pg(h) and Pg′

E Region	1	2	3	4	5	6	7	8	9
Stars	B–P	A–T	A, C–P	B–O	C–N	D–R	C–S	B, D–Q	A–Q
No. of stars	14	19	14	13	11	14	16	14	16
Mean Col.	0·72	0·71	0·29	0·50	0·47	0·39	0·28	0·66	0·54
Mean *Pg′*	8·79	8·80	8·83	8·78	8·76	8·79	8·83	8·78	8·76
Mean *Pg(H)*	8·84	8·66	8·97	8·99	8·47	8·75	8·72	8·84	8·70
Mean *Pg(h)*	8·89	8·94	8·63	8·72	8·65	8·79	8·68	8·88	8·53
Col. Cor. to *Pg(H)*	+·01	+·01	−·01	·00	·00	−·01	−·01	+·01	·00
Col. Cor. to *Pg(h)*	−·01	−·01	+·01	·00	·00	+·01	+·01	−·01	·00
Pg(H) − Pg′	+·06	−·13	+·13	+·21	+·29	−·05	−·12	+·07	−·06
Ph(h) − Pg′	+·09	+·13	−·19	−·06	−·11	+·01	−·14	+·09	−·23
Ph(H) − Pg′ +·02	+·08	−·11	+·15	+·23	−·27	−·03	−·10	+·09	−·04
Pg(h) − Pg′ +·05	+·14	+·18	−·14	−·01	−·06	+·06	−·09	+·14	−·18
Pg(h) − Pg(H) +·03	+·06	+·29	−·29	−·24	+·21	+·09	+·01	+·05	−·14

so that $H = 0^m.11$, $h = 0^m.10$ and $S = 0^m.05$. The corresponding probable errors for the zero points of *Pg(H)*, *Pg(h)* and *Pg′* are $\pm 0^m.10$, $\pm 0^m.09$ and $\pm 0^m.04$. If the differences between the individual magnitudes are treated in a similar manner we get for the probable errors (exclusive of zero point) of the individual *Pg(H)*, *Pg(h)* and *Pg′*, magnitudes $\pm 0^m.055$, $\pm 0^m.141$ and $\pm 0^m.022$ respectively if the twenty large $Pg(H) - Pg'$ differences be excluded, and $\pm 0^m.064$, $\pm 0^m.138$ and $\pm 0^m.041$ if these differences be included. If we combine these probable errors with those for the zero point we get that the probable error of an individual magnitude is about $\pm 0^m.12$ for *Pg(H)*, $\pm 0^m.16$ for *Pg(h)* and $\pm 0^m.05$ for *Pg′*.

It is interesting to notice that these comparisons appear to confirm the value of $\pm 0^m.08$ found by Halm for the probable error of the zero point of *Pg(h)* and indicate that the higher value of $\pm 0^m.14$ found by the Gaposchkins is really due to a probable error of about $\pm 0^m.10$ in the zero points of the Harvard magnitudes.

The systematic differences between the *Pg′*, *Pg(h)* and *Pg(H)* magnitudes that emerge from these comparisons can be expressed by the following relations:—

$$Pg(H) - Pg' = -0^m.02 + 0.06(C.I. - 0.5),$$
$$Pg(h) - Pg' = -0^m.05 - 0.06(C.I. - 0.5) - 0.14(m - 8.35) \qquad (7 < m < 9),$$
$$= -0^m.05 - 0.06(C.I. - 0.5) + 0.12(m - 9.75) \qquad (9 < m < 11).$$

Possible small magnitude-colour effects, which cannot be properly evaluated, have been ignored.

Other Photovisual Magnitudes.—The Harvard magnitudes given in Table I under the heading of *Pv(H)* are the only directly determined photovisual magnitudes with which the *Pv* and *Pv′* systems can be compared. On the other hand, the greater part of the Harvard visual photometry has been reduced to this same photovisual system*, and contains many of the stars in the E region sequences and also many of the stars whose magnitudes are being determined in the $-30°$ to $-35°$ zone.

The derivation of the Harvard photovisual magnitudes is described in *H.A.*, 89 1, 1931. The plates for the E regions were obtained at Arequipa with the 10-inch Metcalf telescope to which was fitted an objective diffraction grating whose constant was about

* *Harv. Mim.*, Ser. iii, Nos. 1 and 2, 1938.

$3^m.58$. Iso-presto plates and a "Rapid Filter Yellow" appear to have been used. The observational material was obtained before 1922. The plates were taken in series with the standard C regions at +15°, but only the zero point was thus obtained. The scale was determined for each plate from the diffraction images of from four to six bright stars. A minimum of four plates was used for each region. The zero point for the whole system of magnitudes was obtained by assuming that the mean of the colour indices of the Ao stars in the C regions was zero. The probable error of an individual photovisual magnitude is given as "less than $\pm 0^m.05$."

The photovisual magnitudes of stars in the Harvard Standard Regions at the South Pole, −75°, −45°, −15° and +15°, were all found with this instrumental equipment. The regions at the North Pole, +75°, +45°, +15° and −15°, were observed with the 16-inch Metcalf telescope at Cambridge. The magnitudes for the northern regions were reduced to the system of the southern ones by means of the stars in common. The colour difference between the 10- and 16-inch Metcalf telescopes proved to be quite large. The resulting magnitudes for the Standard Regions were used to reduce most of the Harvard visual catalogues, the Potsdam Generalkatalog and the Yerkes Actinometry to a single system—that of the 10-inch Metcalf telescope. The relation between these magnitudes (which will be referred to as *HPv*) and the international photovisual ones was found from stars north of +80° and is given as

$$IPv - HPv = +0.10 + 0.06 C.I._i.$$

Intercomparison of the Photovisual Magnitude Systems.—The intercomparison of the various systems of photovisual and visual magnitudes was carried out in a manner similar to that used for the photographic ones, but differences in colour were always examined and, where large, removed before differences in scale were investigated. The results are shown in Tables XIV–XX.

TABLE XIV

$Pv' - Pv$

Pv	6·5	7·0	7·5	8·0	8·5	9·0
C.I. < ·20	...	−·02(3)	·00(14)	+·01(28)	−·02(16)	−·03(5)
·20 < *C.I.* < ·80	−·01(7)	+·01(7)	+·03(10)	·00(23)	−·02(21)	−·05(6)
C.I. > ·80	−·01(18)	·00(5)	+·05(16)	+·02(7)	·00(6)	−·17(1)
All stars	−·01(25)	·00(15)	+·03(40)	+·01(58)	−·02(43)	−·05(12)

C.I.	−·20	·00	+·20	+·38	+·52	+·70	+·95	+1·25	+1·60
Pv < 8·0	−·01(11)	·00(10)	·00(9)	−·01(12)	+·01(9)	+·04(2)	+·03(14)	+ ·02(17)	−·01(12)
Pv > 8·0	·00(10)	−·01(23)	+·01(17)	−·02(13)	−·02(13)	·00(12)	−·03(4)	− ·02(5)	+·01(1)
All stars	·00(21)	·00(33)	+·01(26)	−·02(25)	−·01(22)	+·01(14)	+·02(18)	+ ·01(22)	−·01(13)

The differences between the individual *Pv* and *Pv'* magnitudes show no colour effect, but, rather unexpectedly, a small scale run which changes its sign at $7^m.5$. This scale run can be represented by

$$\begin{aligned} Pv' - Pv &= 0.04(m - 6.7) \qquad 6.5 < m < 7.5 \\ &= -0.05(m - 8.1) \quad 7.5 < m < 9.0. \end{aligned}$$

TABLE XV

Pv(H) − Pv′ (all stars)

C.I.	−·20	·00	+·20	+·38	+·52	+·70	+·95	+1·25	+1·60
Pv < 8·3	−·16(13)	−·08(10)	−·12(7)	+·01(6)	·00(12)	−·09(5)	+·03(4)	+·12(11)	+·17(6)
Pv′ > 8·3	−·03(2)	−·07(10)	−·01(16)	+·04(11)	+·01(6)	−·01(8)	+·08(4)	+·18(10)	+·22(4)
All stars	−·14(15)	−·08(20)	−·04(23)	+·03(17)	·00(18)	−·04(13)	+·06(8)	+·15(21)	+·21(10)

Pv′	6·5	7·0	7·5	8·0	8·5	9·0	9·5	10·0
C.I. < ·20	..	−·17(1)	−·05(10)	−·01(14)	−·02(7)	−·05(5)	+·10(5)	+·24(1)
·20 < *C.I.* < ·80	−·01(5)	−·06(4)	−·15(4)	+·03(14)	+·02(8)	+·08(13)	+·02(6)	−·04(10)
C.I. > ·80	−·01(10)	−·05(2)	−·02(6)	·00(3)	+·08(6)	+·10(9)	+·03(2)	−·47(1)
All stars	−·01(15)	−·07(7)	−·06(20)	+·01(31)	+·02(21)	+·06(27)	+·05(13)	−·05(12)

Average arithmetical difference (with colour) $0^{m}\cdot15$,
(without colour) $0^{m}\cdot12$.

TABLE XVI

Pv(H) − Pv′ against Pv′ (7 large residuals rejected)

C.I.	−·20	·00	+·20	+·38	+·52	+·70	+·95	+1·25	+1·60
Pv′ < 8·3	−·14(12)	−·14(9)	−·12(7)	+·01(6)	·00(12)	−·09(5)	+·03(4)	+·12(11)	+·17(6)
Pv′ > 8·3	−·03(2)	−·07(10)	−·01(16)	+·05(9)	+·01(6)	+·06(7)	+·08(2)	+·18(10)	+·22(4)
All stars	−·13(14)	−·11(19)	−·04(23)	+·03(15)	·00(18)	·00(12)	+·05(6)	+·15(21)	+·19(10)
0·18 (*C.I.* −·6)	−·14	−·11	−·07	−·04	−·01	+·02	+·06	+·12	+·18
0·14 (*C.I.* −·6)	−·11	−·08	−·06	−·03	−·01	+·01	+·05	+·09	+·14

Pv′	6·5	7·0	7·5	8·0	8·5	9·0	9·5	10·0
C.I. < ·20	...	−·17(1)	−·05(10)	−·05(13)	−·02(7)	−·05(5)	+·10(5)	+·24(1)
·20 < *C.I.* < ·80	−·11(4)	−·06(4)	−·15(4)	+·03(14)	+·02(8)	+·05(12)	+·02(6)	+·06(8)
C.I. > ·80	−·01(10)	−·05(2)	−·02(6)	·00(3)	+·08(6)	+·05(8)	+·03(2)	
All stars	−·04(14)	−·07(7)	−·06(20)	−·01(30)	+·02(21)	+·03(25)	+·05(13)	+·08(9)

Average arithmetical difference (with colour) $0^{m}\cdot13$,
(without colour) $0^{m}\cdot11$.

The differences between the individual *Pv(H)* and *Pv′* magnitudes, when cleared approximately for zero point errors region by region, average $0^{m}\cdot15$; when cleared for colour by means of the relation

$$Pv(H) - Pv' = 0\cdot18(C.I. - 0\cdot6),$$

this average is reduced to $0^{m}\cdot12$. If seven large differences each exceeding $0^{m}\cdot4$ are excluded, these averages are reduced to $0^{m}\cdot13$ and $0^{m}\cdot11$ respectively. Two comparisons

of $Pv(H)$ and Pv' were therefore made, the one including the seven stars, the other excluding them. The resulting colour relations are much the same in both cases, but the scale relations differ. If the seven stars are included the scale relation is rather irregular but, on the whole, indicates no systematic scale difference between the $Pv(H)$ and Pv' systems. On the other hand, if these stars are excluded, a fairly definite scale difference emerges. It can be expressed as

$$Pv(H) - Pv' = 0{\cdot}045(m - 8{\cdot}3) \qquad 6{\cdot}5 < m < 10{\cdot}0.$$

This difference in scale is also indicated by the way in which the colour relation for the faint stars differs from that for the bright stars.

TABLE XVII

HPv − Pv(H)

C.I.	−·20	·00	+·20	+·38	+·52	+·70	+·95	+1·25	+1·60
HPv − Pv(H)	+·02(6)	−·03(9)	+·09(13)	−·10(12)	+·06(7)	+·03(4)	−·04(3)	+·07(14)	+·23(5)

Pv(H)	6·0	6·5	7·0	7·5	8·0	8·5	9·0	9·5
HPv − Pv(H)	+·12(4)	−·06(10)	+·25(1)	+·03(10)	·00(20)	·00(8)	+·02(8)	−·01(12)

Average arithmetical difference $0^{m}{\cdot}17$.

About ninety stars are common to the *HPv* and *Pv′* systems, and about seventy of these are also included in the *Pv(H)* system. In intercomparing these magnitudes no attempt was made to split them into groups or to correct for zero point when investigating the scale and colour relations. The *HPv* magnitude of the star B of E1 was altered by one magnitude, on the assumption that it was misprinted by this amount in the mimeogram. The scale and colour relations between *HPv* and *Pv(H)* are irregular but give no evidence of any systematic difference.

TABLE XVIII

HPv − Pv′

C.I.	−·20	·00	+·20	+·38	+·52	+·70	+·95	+1·25	+1·60
HPv − Pv(H)	−·17(7)	−·07(11)	+·01(15)	+·01(14)	+·06(8)	+·08(5)	+·05(6)	+·13(16)	+·33(10)
·22 (*C.I.* −·4)	−·13	−·09	−·04	·00	+·03	+·07	+·12	+·19	+·26

Pv′	6·0	6·5	7·0	7·5	8·0	8·5	9·0	9·5
HPv − Pv′	+·11(6)	−·11(14)	+·09(8)	+·04(14)	−·02(20)	−·02(10)	+·04(11)	+·07(9)

Average arithmetical difference (with colour) 0·16,
(colour removed) 0·13.

Between *HPv* and *Pv'*, on the other hand, there is a marked colour difference which can be represented by

$$HPv - Pv' = 0{\cdot}22(C.I. - 0{\cdot}4).$$

Corrected for colour by means of this relation and arranged according to magnitude, the differences between *HPv* and *Pv'* magnitudes show no signs of a systematic scale difference.

TABLE XIX

Zero Point Differences between Pv(H), HPv and Pv'

E Region	1	2	3	4	5	6	7	8	9
No. of stars	8	9	4	7	5	12	7	11	9
Mean Col.	0·47	0·80	0·07	0·54	0·75	0·46	0·39	0·73	0·60
Mean *Pv'*	7·47	7·77	8·38	8·23	7·57	8·37	8·41	7·94	8·06
Pv' (*C.I.* = ·50)	7·46	7·83	8·29	8·24	7·62	8·36	8·39	7·99	8·08
Mean *Pv(H)*	7·48	7·80	8·14	8·43	7·47	8·36	8·34	8·13	8·16
Mean *HPv*	7·46	7·85	8·20	8·30	7·56	8·46	8·45	8·06	8·09
Pv(H) – Pv'	+·02	−·03	−·15	+·19	−·15	·00	−·05	+·14	+·08
HPv – Pv'	·00	+·02	−·09	+·06	−·06	+·10	+·06	+·07	+·01
HPv – Pv(H)	−·02	+·05	+·06	−·13	+·09	+·10	+·11	−·07	−·07

The zero differences between the various regions are shown in Table XIX. Only stars common to all three systems have been used. The *Pv'* magnitudes are adjusted to the colour system of the *HPv* and *Pv(H)* magnitudes for a mean colour index of $0^m{\cdot}50$. There is a systematic difference of $0^m{\cdot}01$ in zero point between *HPv* and *Pv'*, of $0^m{\cdot}01$ between *Pv(H)* and *HPv* and of $0^m{\cdot}02$ between *HPv* and *Pv'*. The arithmetical mean for the nine regions of the zero differences is $0^m{\cdot}09$ for *Pv(H) – Pv'*, $0^m{\cdot}05$ for *HPv – Pv'* and $0^m{\cdot}08$ for *HPv – Pv(H)*. If we treat these average differences in the same way as we treated the analogous differences for the photographic magnitudes, we get that the probable errors of the zero point are approximately $\pm 0^m{\cdot}02$ for the *HPv* magnitudes, $\pm 0^m{\cdot}07$ for the *Pv(H)* magnitudes and $\pm 0^m{\cdot}04$ for the *Pv'* magnitudes. Treating the accidental differences of the individual magnitudes in a similar way, we get that the square of the portion of the part of the mean difference to be attributed to the *Pv'* magnitudes is negative—a reminder that this method of evaluating the probable errors is not above suspicion, especially when it is based on rather limited data. Taking the accidental probable error of the *Pv'* magnitudes to be zero, those to be assigned to the *HPv* and *Pv(H)* magnitudes come out as $\pm 0^m{\cdot}11$ and $\pm 0^m{\cdot}09$ respectively. If we combine these probable errors with those for the zero point we get that the probable error of an individual magnitude is about $\pm 0^m{\cdot}11$ for *HPv*, $\pm 0^m{\cdot}11$ for *Pv(H)* and $\pm 0^m{\cdot}04$ for *Pv'*.

The more elaborate comparison of the zero points of the *Pg(H)* and *Pv'* magnitudes shown in Table XX confirms the value of $0^m{\cdot}09$ as the arithmetical mean of the differences in zero point, though the value of this difference for any particular region varies from that found when fewer stars were included in the comparison.

A much stronger determination of the relations between the *HPv* and *Pv'* magnitudes can be obtained from the stars in common in the $-30°$ to $-35°$ zone. There are about 700 such stars included in the first 5000 stars of the zone catalogue. The colour relation found by arranging the differences according to the Cape colour index can be represented by

$$HPv - Pv' = 0{\cdot}14(C.I. - 0{\cdot}5) - 0{\cdot}09.$$

TABLE XX

Zero Point Differences between Pv(H) and Pv′

E Region	1	2	3	4	5	6	7	8	9
Stars	A, B, D–N O–R	B–U	A, C–I	A–M O, P	A–O	A, C–R	A, C, D, H, I, L–O	B, D–S	A–Q
No. of stars	15	19	8	14	14	16	9	16	16
Mean Col.	0·71	0·74	−0·02	0·40	0·42	0·36	0·25	0·72	0·54
Mean *Pv′*	8·21	8·20	8·21	8·24	8·23	8·16	8·18	8·21	8·23
Pv′ (*C.I.* = ·50)	8·25	8·24	8·12	8·22	8·22	8·13	8·13	8·25	8·24
Mean *Pv*(*H*)	8·29	8·30	8·07	8·37	8·05	8·11	8·08	8·36	8·38
Pv(*H*) − *Pv′*	+·04	+·06	− ·05	+·15	−·17	+·02	−·05	+·11	+·14

TABLE XXI

HPv − Pv′ (*Zone* −30° *to* −35°)

C.I.	−0·35	−0·20	0·00	+0·20	+0·40	+0·60
HPv − Pv′	−·22(16)	−·22(56)	−·15(59)	−·12(69)	−·08(83)	−·03(48)
0·14 (*C.I.* − 0·5) − 0·09	−·21	−·19	−·16	−·13	−·10	−·08

C.I.	+0·80	+1·00	+1·25	+1·55	+1·85	+2·15
HPv − Pv′	−·03(27)	−·02(83)	−·02(110)	+·06(74)	+·05(41)	+·16(4)
0·14 (*C.I.* − 0·5) − 0·09	−·05	−·02	+·02	+·06	+·10	+·14

Pv′ / *C.I.*	5·0	5·5	6·0	6·5	7·0	7·5	8·0	8·5	9·0	9·5
−0·20		−·03(3)	−·15(4)	−·13(14)	−·21(27)	−·30(24)	−·23(11)	−·18(10)	−·06(3)	−·19(2)
+0·25		−·02(4)	−·04(3)	−·06(21)	−·12(33)	−·15(43)	−·18(28)	−·09(24)	−·02(19)	−·02(15)
+1·00	·00(4)	−·03(13)	+·07(9)	−·02(36)	−·06(62)	−·05(60)	−·09(29)	+·03(25)	+·09(28)	+·22(6)
+1·70	+·26(2)	+·07(2)	+·11(8)	+·06(33)	+·01(35)	−·01(25)	+·09(6)	+·24(9)	+·38(2)	
c		+·05	+·14	+·10	+·11	+·15	+·17	+·23	+·24	
d		−·04	−·10	−·11	−·17	−·23	−·22	−·16	−·07	
·06(*m* − 5·0)		+·03	+·06	+·09	+·12	+·15	+·18	+·21	+·24	
−·10(*m* − 5·2)		−·03	−·08	−·13	−·18	−·23				
+·15(*m* − 9·5)							−·22	−·15	−·07	

It will be noticed that the colour coefficient in this relation is appreciably smaller than that found from the stars at −45° (0·22) or that found from the *Pv*(*H*) magnitudes (0·18) which are supposed to be on the same colour system as the *HPv* magnitudes. This colour coefficient is, of course, only an average value, and, as can be seen from the second half of Table XXI where the differences *HPv − Pv′* have been split into four colour groups and arranged according to magnitude, the colour coefficient appears to vary

with the magnitude. It was assumed that for each magnitude subdivision the difference $HPv - Pv'$ could be expressed as $c.C.I. + d$, and the values of c and d were evaluated by the method of least squares, the mean colours of the four colour subdivisions being taken as -0.2, $+0.25$, $+1.0$ and $+1.7$. The values of c and d that resulted are shown in the last part of Table XXI. The value of c is fairly well represented by

$$c = 0.06(m - 5.0),$$

while d can be represented by

$$\begin{aligned} d &= -0.10(m - 5.2) \qquad 5.5 < m < 7.8, \\ &= +0.15(m - 9.5) \qquad 7.8 < m < 9.0. \end{aligned}$$

It thus appears that the difference $HPv - Pv'$ can be expressed as

$$\begin{aligned} HPv - Pv' &= 0.06(m - 5.0)C.I. - 0.10(m - 5.2) \qquad 5.5 < m < 7.8, \\ &= 0.06(m - 5.0)C.I. + 0.15(m - 9.5) \qquad 7.8 < m < 9.0. \end{aligned}$$

The average value of Pv' for the 700 odd stars used in this comparison is about 7·4, so that the corresponding average value of c should be 0·144—in good agreement with the value of 0·14 found above. The average value of Pv' for the $Pv(H)$, Pv' comparison was about 8·3, so that one would expect a value for c of about 0·198. The value actually found was 0·18. For the HPv, Pv' comparison at $-45°$ the expected value is about 0·17, while the value actually found was 0·22.

This increase of the colour coefficient with magnitude and the bend in the scale at $7^{m}.8$ recall similar results found by Seares * when comparing the Harvard visual magnitudes for the polar sequence with the international ones. In this case the bend of scale was at $9^{m}.5$ and was attributed by Seares to the change over from measures made with the 4-inch meridian photometer to those made with the 12-inch one. Most of the observations on which the HPv magnitudes used in the present comparison are based must have been made by Bailey with the 4-inch photometer, though it is possible that a few of the fainter ones were made with the Rumford photometer. It is hoped that a more detailed comparison between the HPv and Pv' magnitudes will be made when the reduction of the Pv' magnitudes for the whole $-30°$ to $-35°$ zone is complete. This comparison will be based on about 1500 stars. The change in scale that was found in the Cape Astrographic Zone magnitudes may well be related to this change in the Harvard visual scale, for it will be recalled that one of the three ways in which the $Pg(h)$ scale was obtained was by the application of mean colour indices to Harvard visual magnitudes.

Reduction to the International Magnitude System

The Cluster Magnitudes.—A number of stars in the Pleiades, Hyades and Praesepe have been observed in order to furnish material for a comparison between the Cape magnitudes and those of the north polar sequence. Six pairs of plates were taken for each of the Hyades and Praesepe, each plate having four 3-minute exposures, the first and last being on the cluster, the second and third on an E region, the zenith distance of which was changing the more rapidly of the two. In the case of the Pleiades only three such pairs of plates were obtained, but there were three similar pairs taken earlier in our photometric programme. The results from these latter plates, which were obtained under rather poor conditions, were assigned only one-third the weight of the others. The Hyades were compared with E1, E4 (twice), E5 (twice) and E9; Praesepe with E1, E2 (twice), E5 and E6 (twice), and the Pleiades with E4 and E9. The plates were taken with the cluster and E region at equal zenith distances. Differential extinction corrections were applied in the case of the Hyades and Praesepe but not for the Pleiades,

* *Ap. J.*, 61, 284, 1925; *Mt. W. Cont.*, 288.

where the stars observed are much closer together. The selective colour extinction shown in Table IV has not been applied, though its effect may be appreciable. The resulting magnitudes, which should be on the *Pg*, *Pv* system, are shown in columns two and three of Tables XXII, XXIII and XXIV. The first columns of Tables XXII and XXIII gives the numbers in Ramberg's catalogues*, from which the stars were selected, while the first column of Table XXIV gives the Gaultier number, though the stars are actually numbers 10 to 58 of the list given by Trumpler.†

TABLE XXII

Magnitudes of Stars in the Hyades

No.	*Pg*	*Pv*	*C.I.*	*Sp.*	*Pg(S)*	*Pv(S)*	*IPg*	*IPv*	$C.I._4$
8	9·62	7·88	1·74	gKo	9·55	8·06	9·63	8·12	+1·51
10*	7·46	6·94	0·52	F5	7·55	7·25	7·58	7·01	+0·57
18	8·40	8·11	0·29	Ao	8·29	8·23	8·39	8·15	+0·24
21*	9·99	8·94	1·05	dG8	9·87	9·00	9·89	9·09	+0·80
33*	8·81	8·16	0·65	dGo	8·79	8·34	8·79	8·25	+0·54
34	9·11	8·63	0·48	F5	9·00	8·67	9·04	8·70	+0·34
36*	8·17	7·53	0·64	F8	8·15	7·72	8·22	7·62	+0·60
38*	7·34	6·98	0·36	F5	7·38	7·15	7·45	7·03	+0·42
41*	8·38	7·72	0·66	dGo	8·36	7·80	8·41	7·81	+0·60
66*	6·84	6·45	0·39	F5	7·01	6·78	7·01	6·50	+0·51
72	7·83	7·51	0·32	F2	7·84	7·75	7·89	7·55	+0·34
82*	7·99	7·43	0·56	F8	8·07	7·60	8·05	7·51	+0·54
91*	8·69	7·95	0·74	dGo	8·62	8·06	8·69	8·05	+0·64
97	8·70	7·26	1·44	dG5	8·78	7·58	8·78	7·46	+1·32
106*	8·74	7·99	0·75	dGo	8·71	8·15	8·74	8·10	+0·64
108	9·76	9·05	0·71	dGo	9·51	9·34	9·65	9·15	+0·50
112	8·32	6·53	1·79	gKo	8·47	7·07	8·48	6·78	+1·70
144*	7·91	7·36	0·55	F8	7·98	7·62	7·98	7·44	+0·54
169	9·64	7·93	1·71	gKo	9·59	8·34	9·65	8·17	+1·48
190*	8·44	7·78	0·66	dGo	8·42	7·75	8·46	7·87	+0·59
193	8·23	7·97	0·26	Ao	8·20	8·20	8·23	8·01	+0·22
199*	7·00	6·56	0·44	F8	7·13	6·93	7·16	6·62	+0·54
222*	9·93	8·96	0·97	dKo	9·83	9·05	9·83	9·10	+0·73
237	8·70	8·18	0·52	F8	8·69	8·39	8·68	8·25	+0·43
245	9·87	8·44	1·43	gG8	9·69	8·48	9·82	8·64	+1·18
248*	9·75	8·77	0·98	dG8	9·73	8·92	9·67	8·91	+0·76
249	9·78	8·98	0·80	dGo	9·60	9·15	9·67	9·09	+0·58
261*	6·81	6·54	0·27	F2	6·94	6·72	6·97	6·58	+0·39
274	8·03	5·94	2·09	gM	8·26	6·56	8·26	6·23	+2·03
276	8·64	8·14	0·50	F5	8·59	8·27	8·63	8·21	+0·42
280	8·25	7·85	0·40	F5	8·25	7·92	8·26	7·91	+0·35
292	9·51	9·10	0·41	A3	9·38	9·03	9·39	9·16	+0·23
323*	9·76	8·75	1·01	dKo	9·73	8·87	9·68	8·89	+0·79
327*	9·42	8·57	0·85	dG5	9·37	8·65	9·35	8·69	+0·66
347	9·04	8·30	0·74	dGo	8·96	8·33	9·01	8·40	+0·61
354*	9·32	8·31	1·01	dKo	9·38	8·49	9·28	8·45	+0·83
364*	8·50	7·85	0·65	dGo	8·50	8·06	8·52	7·94	+0·58

Note.—A physical member of the cluster is denoted by an asterisk in the first column.

The *Pg* magnitudes for the Hyades were compared only with the Hertzsprung-Ramberg magnitudes shown in column six of Table XXII. Those for Praesepe were compared both with the magnitudes shown in column six of Table XXIII (which are

* *Stok. Obs. An.*, 13, No. 9, 1941. † *L.O.B.*, 333, 1921.

taken from Ramberg's catalogue) and with the magnitudes given by Hertzsprung *, Vanderlinden †, Strobel ‡, Bernheimer and Reimer § and by Schilt.‖ In addition, use was made of Ramberg's monochromatic magnitudes corrected by his Table 14.

TABLE XXIII

Magnitudes of Stars in Praesepe

No.	*Pg*	*Pv*	*C.I.*	*Sp.*	*Pg(S)*	*Pv(S)*	*IPg*	*IPv*	*C.I.*$_i$
32	9·75	8·61	1·14	gKo	9·52	8·77	9·69	8·77	+ ·92
57*	7·24	6·54	0·70	dGo	7·32	7·15	7·40	6·64	+ ·76
100*	7·59	7·56	0·03	A2	7·38	7·45	7·64	7·56	+ ·08
181	8·57	7·97	0·60	F8	8·30	8·33	8·58	8·05	+ ·53
190*	9·05	8·65	0·40	Fo	8·86	8·90	8·97	8·71	+ ·26
193*	7·94	7·82	0·12	A2	7·71	7·78	7·96	7·84	+ ·12
200*	8·53	8·33	0·20	A5	8·42	8·52	8·49	8·36	+ ·13
206*	6·84	6·81	0·03	A5	6·81	6·86	6·97	6·81	+ ·16
257	8·30	7·81	0·49	F8	8·15	8·14	8·32	7·88	+ ·44
279*	8·36	8·17	0·19	A5	8·23	8·29	8·34	8·20	+ ·14
322*	7·69	7·46	0·23	Fo	7·51	7·57	7·75	7·49	+ ·26
328*	8·77	8·52	0·25	A5	8·61	8·65	8·72	8·56	+ ·16
330	9·26	8·80	0·46	F2	9·04	9·13	9·17	8·86	+ ·31
381*	6·84	6·75	0·09	Fo	6·83	6·83	6·98	6·76	+ ·22
387*	7·82	7·70	0·12	A3	7·67	7·72	7·85	7·72	+ ·13
390*	7·55	6·45	1·10	gG8	7·63	6·89	7·72	6·60	+1·12
402*	7·49	7·40	0·09	A3	7·49	7·51	7·56	7·41	+ ·15
427*	7·36	6·25	1·11	gG5	7·35	6·66	7·55	6·41	+1·14
438*	6·48	6·76	−0·28	Ao	6·55	6·67	6·62	6·72	− ·10
448*	7·67	7·64	+0·03	A2	7·52	7·55	7·71	7·64	+ ·07
452*	7·89	7·73	+0·16	Ao	7·77	7·79	7·92	7·75	+ ·17
454*	6·98	6·82	+0·16	Fo	6·95	6·98	7·11	6·84	+ ·27
456*	7·44	6·28	+1·16	gG5	7·52	6·88	7·63	6·44	+1·19
457*	8·20	8·07	+0·13	Ao	8·02	8·04	8·19	8·09	+ ·10
469*	6·30	6·36	−0·06	A2	6·45	6·49	6·48	6·35	+ ·13
482*	9·00	8·67	0·33	A3	8·79	8·86	8·93	8·72	+ ·21
496*	6·97	6·92	0·05	A5	6·90	6·87	7·09	6·93	+ ·16
514*	6·88	6·85	+0·03	A3	6·77	6·80	7·00	6·85	+ ·15
539*	8·52	8·37	+0·15	A3	8·33	8·42	8·48	8·39	+ ·09
540	6·75	6·80	−0·05	A2	6·54	6·60	6·88	6·79	+ ·09
564	9·51	8·35	1·16	gG5	9·33	8·58	9·47	8·51	+ ·96
587*	7·92	6·80	1·12	gKo	7·81	7·15	8·05	6·96	+1·09
591*	8·87	8·50	0·37	Fo	8·53	8·64	8·81	8·55	+ ·26
609*	8·17	8·02	0·15	A3	7·93	7·94	8·17	8·04	+ ·13
759	9·08	7·85	1·23	gKo	8·98	8·77	9·10	8·02	+1·08
823	8·29	8·04	0·25	A2	8·05	8·05	8·29	8·08	+ ·21
825	8·10	7·57	0·53	F8	7·84	7·88	8·15	7·64	+ ·51
842	8·64	8·43	0·21	A3	8·43	8·49	8·59	8·46	+ ·13
844	8·04	7·54	0·50	dGo	7·73	7·75	8·10	7·61	+ ·49

Note.—A physical member of the cluster is denoted by an asterisk in the first column.
The *Pv*(*S*) magnitudes for Nos. 57, 456, 759 were not used for comparison purposes.

These magnitudes are not all independent. Ramberg's, for example, depend on Vanderlinden's; Vanderlinden's depend for scale and zero point on Hertzsprung's, which in turn depend for zero point on the Göttingen Actinometric B, as also do Schilt's. The *Pg* magnitudes for the Pleiades were compared with the magnitudes shown in the sixth column of Table XXIV, which are from a list prepared by Hertzsprung

* *A.N.*, 205, 71, 1917. † *Étude de L'amas de Praesepe*, 1933.
‡ Strobel, *A.N.*, 253, 173, 1934. § Wien, *Mit.*, 4, 1935. ‖ *Yale U.O., Trans.*, 10, 1934.

TABLE XXIV

Magnitudes of Stars in the Pleiades

No.	*Pg*	*Pv*	*C.I.*	*Sp*	*Pg(S)*	*Pv(S)*	*IPg*	*IPv*	*C.I.*$_i$
46		5·77		B8	5·49	5·80			
76		5·90		B8	5·69	5·94			
252		6·28		B8	6·04	6·32			
78		6·56		B9	6·37	6·56			
133		6·42		A0	6·31	6·48			
236		6·73		B9	6·56	6·78			
113		6·94		B9	6·76	6·97			
267		6·83		B9	6·77	6·91			
145		6·92		B9	6·84	7·01			
134		7·13		A0	6·95	7·13			
295	6·84	7·04	−0·20	A0	7·00	7·08	6·95	7·01	− ·06
191	6·92	7·05	−0·13	A0	7·03	7·04	7·03	7·03	·00
137*a*	7·08	7·32	−0·24	B9	7·28	7·31	7·15	7·29	− ·14
63	7·17	7·23	−0·06	B9	7·24	7·30	7·25	7·22	+ ·03
94	7·33	7·49	−0·16	A0	7·44	7·46	7·38	7·47	− ·09
263	7·51	7·60	−0·09	A0	7·59	7·59	7·55	7·59	− ·04
281	7·45	7·51	−0·06	A2	7·52	7·57	7·50	7·50	·00
231	7·55	7·60	−0·05	A0	7·60	7·64	7·59	7·59	·00
135	7·82	7·74	+0·08	A0	7·85	7·79	7·85	7·75	+ ·10
141	7·87	7·87	0·00	A0	7·86	7·89	7·88	7·87	+ ·01
73	8·02	7·92	+0·10	A0	7·99	7·95	8·03	7·93	+ ·10
239	8·09	8·08	+0·01	A0	8·10	8·11	8·08	8·08	·00
8	8·23	8·12	+0·11	A2			8·21	8·14	+ ·07
56	8·25	8·08	+0·17	A3	8·21	8·15	8·24	8·10	+ ·14
251	8·30	8·20	+0·10	A2			8·28	8·21	+ ·07
227	8·30	8·18	+0·12	A2	8·34	8·24	8·28	8·20	+ ·08
	8·22	8·00	+0·22	A5			8·22	8·03	+ ·19
1	8·44	8·29	+0·15	A5			8·41	8·31	+ ·10
27	8·45	8·17	+0·28	A5	8·38	8·29	8·43	8·21	+ ·22
132	8·48	8·30	+0·18	A0	8·48	8·43	8·45	8·33	+ ·12
99	8·41	8·09	+0·32	A0	8·44	8·23	8·40	8·13	+ ·27
177	8·63	8·29	+0·34	A3	8·60	8·35	8·60	8·34	+ ·26
121	8·66	8·41	+0·25	A2	8·63	8·51	8·62	8·45	+ ·17
204	8·60	8·34	+0·26	A3	8·59		8·56	8·38	+ ·18
86*a*	8·26	8·08	+0·18	A3		8·10	8·25	8·11	+ ·14
44	8·94	8·58	+0·36	A0	8·90	8·69	8·88	8·63	+ ·25
59	8·96	8·69	+0·27	A2	8·87	8·73	8·88	8·73	+ ·15
118	8·67	8·36	+0·31	A2	8·66	8·40	8·63	8·40	+ ·23
126	9·10	8·72	+0·38	G0	9·00	8·81	9·02	8·77	+ ·25
86*b*	8·84	7·42	+1·42	K2			8·91	7·62	+1·29
45	9·35				9·28	9·07			
24	9·55					9·17			
	9·54								
245	9·56					9·22			
66	10·02				9·85	9·52			
104	9·80				9·67	9·47			
123	9·97								
173	9·84				9·69	9·41			
193	9·57				9·46	9·22			

Note.—*Pg* and *Pv* shown for 137*a* are really for 137*a* and 137*b* combined.

in 1939 for the use of the late E. G. Williams. They are substantially the same as those given in *Memoirs, Royal Danish Academy*, Ser. 8, 4, No. 4, 1923.

The Photographic Magnitudes.—The comparison of *Pg* with the standard magnitudes was carried out in the same way as the comparisons made earlier in this paper. A rough scale correction was determined and applied before the colour correction was investigated. In determining the final scale relation, the differences between the magnitudes to which the adopted colour correction had been applied were plotted both against *Pg* and against the standard magnitudes with which the *Pg* magnitudes were being compared. This was done partly to diminish the accidental error and partly to eliminate any "statistical error" that might arise, though in comparisons such as these the statistical error is likely to be vanishingly small. The results are given below.

It must be remarked that cluster magnitudes are not the most suitable for determining the relations between magnitude systems, as there is usually a correlation between the colours of the stars and their magnitudes so that the colour and scale relations become interlocked. Especially is this the case for the Pleiades where there is between magnitudes 7 and 9 a linear relation between the colour and the magnitude; expressible as $C.I. = 0{\cdot}29\ (Pg - 7{\cdot}7)$. In the case of the Hyades and Praesepe magnitudes, where several non-cluster stars and red giants have been included, such a close correlation does not exist and we can separate the colour and scale relations with a fair degree of certainty.

If the colour relations be put in the form

$$Pg\ (\text{Standard}) - Pg\ (\text{Cape}) = c.C.I._{\text{Cape}} + \text{const.}$$

the values of c found from the comparisons are

$c = 0{\cdot}11$	(Hyades)
$0{\cdot}12$	(Praesepe—Ramberg Cat.)
$0{\cdot}09$	(Praesepe—Hertzsprung)
$0{\cdot}11$	(Praesepe—Vanderlinden)
$0{\cdot}06$	(Praesepe—Ramberg mono. mags.)
$0{\cdot}08$	(Praesepe—Schilt)

The colour relation of Schilt's magnitudes to the international system is slightly doubtful. According to the Gaposchkins * there is no appreciable colour difference. On the other hand Schilt's magnitudes for the 50° to 60° zone (which was observed later and compared directly with the north polar sequence) appear to have a colour coefficient of the order of 0·05 in the sense that

$$IPg - Pg\ (\text{Schilt}) = 0{\cdot}05\ C.I._i + \text{const.}$$

This would make the value of c derived from the comparison with Schilt's magnitudes about 0·13.

The value adopted for c was 0·11.

If one magnitude ($Pg + 0{\cdot}11\ C.I.$) equals R standard magnitudes, the values of R found were

$0{\cdot}885$,	$0{\cdot}894$;	(Hyades)
$0{\cdot}905$,	$0{\cdot}911$;	(Praesepe—Hertzsprung)
$0{\cdot}885$,	$0{\cdot}897$;	(Praesepe—Vanderlinden)
$0{\cdot}888$,	$0{\cdot}881$;	(Praesepe—Ramberg Cat.)

the first value being that found when the differences in the magnitudes were plotted against the Cape magnitudes, the second that when these differences were plotted against the standard magnitudes. The values of R found from the twenty-four stars of the Pleiades for which Cape colour indices are available are 0·865 and 0·877, while if all

* *H.B.*, 902, 3, 1936.

the available photographic magnitudes are used and the scale so found is adjusted for a change in colour of 0·29 per magnitude, the values of R are 0·877 and 0·881. These values are appreciably smaller than those found for the Hyades and Praesepe. It may be that the correction given in Table IV should be taken into account. In round figures this correction amounts to $0^m.01$ per unit change of colour for each 0·1 increase in secant zenith distance. The average zenith distance of the Pleiades was about 58°, so that sec z was about 1·887, or 0·65 larger than that to which the *Pg* magnitudes refer. That is to say, the scale observed for the Pleiades will differ from the average scale by $0^m.01 \times 0.29 \times 6.5$ per magnitude, *i.e.* by $0^m.019$ per magnitude. The effect of the differential colour extinction is to make blue stars appear fainter, *i.e.* for the Pleiades the brighter stars will appear a little too faint. Thus 0·019 should be added to the value of the scale observed for the Pleiades, making it 0·894.

The value adopted for R was 0·890.

There remains the zero point to be fixed. 8·00 *Pg* was found to correspond to

8·02 (Pleiades—Hertzsprung)
7·92 (Pleiades—Schilt)
7·98 (Hyades)
7·83 (Praesepe—Ramberg Cat.)
7·73 (Praesepe—Hertzsprung)
7·70 (Praesepe—Vanderlinden)
7·73 (Praesepe—Bernheimer and Reimer)
7·86 (Praesepe—Ramberg mono. mags.)
7·61 (Praesepe—Schilt)

As was remarked before, most of the Praesepe magnitudes depend for their zero on Göttingen Actinometrie B. The relation of this catalogue to the international system does not appear to be well known. Judging by the Göttingen Polar Catalogue a zero correction of the order of 0·07 should be applied. Miss Hill's discussion of Schilt's magnitudes * indicates a correction of the order of 0·09. This brings the zero point for the Pleiades in good agreement with that derived from Hertzsprung's magnitudes, but does not throw light on the big discrepancy for Praesepe. According to Ramberg, the only set of Praesepe magnitudes directly connected with the north polar sequence are those of Strobel. If we confine our attention to the 20 stars with Cape magnitudes between 7·00 and 9·00 common to both sets of magnitudes, we find that the average Cape magnitude is 8·16 and the average Strobel magnitude 8·15. (No attempt was made to correct either set of magnitudes for colour or scale.) It was decided not to apply any zero correction to 8·00 *Pg* (Cape) until further observations indicate that it is necessary.

This leaves a discrepancy in the zero point for Praesepe of about $0^m.2$ to be explained. I am unwilling to attribute it all to the Cape magnitudes on account of their internal consistency, which indicates a zero error of the order of $0^m.02$, which would be even smaller if one plate taken on a rather damp night were rejected. Its rejection would alter the zero point by $0^m.02$ at the most. In passing it may be remarked that the chief cause in the variation of the observed zero point between successive exposures seems to be the humidity of the atmosphere. Situated as the observatory is, within a mile of the sea, it is almost impossible at certain times of the year to pick nights when the humidity is low. The zero points found from the photovisual observations are always more consistent, a fact that may be attributed to the filter in front of the plate which protects it from the damp air. It would appear, therefore, that in moist locations the accuracy of photographic photometry could be increased by using a plain glass filter in front of the plate.

* *A.J.*, 50, 55, 1942.

To summarise, the best formula for transforming the *Pg* system to the international one appears to be

$$IPg = 0{\cdot}890\ Pg + 0{\cdot}11\ C.I._{\text{Cape}} + 0{\cdot}880,$$

this formula being valid between about $6^{m}{\cdot}5$ and $10^{m}{\cdot}0$, though it will probably be safe to extrapolate it to the limit of the *Pg'* magnitudes. This formula can also be expressed in the form

$$IPg = Pg - 0{\cdot}11\ Pv + 0{\cdot}880.$$

The Photovisual Magnitudes.—With the data at present available it does not seem possible to reduce the photovisual magnitudes to the international system with the same degree of certainty that has been achieved for the photographic magnitudes. Of the standard magnitudes available, those for the Pleiades (which are shown in the seventh column of Table XXIV) are probably nearest to the international scale. These are based on the visual observations of Müller and Kempf *, which are presumably on the normal Potsdam scale, and on the photovisual observations of Parsons.† A correction equal to $-0^{m}{\cdot}20 + 0{\cdot}09\ C.I.$ was applied to Müller and Kempf's magnitudes, while one of $+0^{m}{\cdot}10$ was applied to those of Parsons.

The standard magnitudes for Praesepe shown in column seven of Table XXIII were derived by applying a colour index obtained from Vanderlinden's effective wave-lengths to the photographic magnitudes given in column six. The formula used to reduce the effective wave-lengths to colour indices was

$$\lambda_e = 4242\ A. + 193\ C.I.,$$

a formula which was found by Vanderlinden himself from direct observations of the polar sequence. The individual magnitudes found in this way will not be of high accuracy, but as a series they should be close to the international system. The magnitudes for stars 57, 456 and 759 have been rejected as the colour indices found from the effective wave-lengths do not agree with those found by the other observers.

The standard magnitudes given for the Hyades in column seven of Table XXII are Graff's visual magnitudes.‡ The relationship of these magnitudes, which were obtained at Bergedorf, to the international system is not given. It does not seem to be quite the same as that for Graff's visual magnitudes for the Pleiades § or for Praesepe.‖

The *Pv* magnitudes were also compared with all the available Potsdam visual and Harvard photovisual magnitudes, and for Praesepe with the photovisual magnitudes of van den Bos ¶ and with those of Bernheimer and Reimer.

In view of the uncertainty of the relationship between the standard magnitudes and the international system, it was decided to derive the colour correction to the *Pv* magnitudes from the colour relation between *Pv'* and the Harvard photovisual system which had been found from about 700 stars in the $-30°$ to $-35°$ zone, though the resulting colour coefficient will only be as accurate as the Harvard photovisual magnitudes (which are the synthesis of several different series of observations) are homogeneous. The relationship between the Harvard and international photovisual systems given by Mrs. Gaposchkin depends on stars north of $+80°$. Since it was made, the Mt. Wilson catalogue of such stars * has been published, and it seems desirable to repeat the comparison using these new data. Such a comparison has been made by Seares for 170 of the brighter stars. Seares finds 0·04 as the colour coefficient instead of 0·06, but on the average the total correction is nearly the same as that found by Mrs. Gaposchkin. In spite of Seares' comparison it seemed worth while to repeat the comparison using all the stars of Table V of *H.A.*, **89**, 195, 1938, which are common to both catalogues. The results of this comparison are shown in Table XXV.

Only two stars ($+80°459$ and $87°41$) were rejected on account of abnormally large

* *A.N.*, **150**, 193, 1899. † *Ap. J.*, **47**, 38, 1918. ‡ *A.N.*, **220**, 135, 1924.
§ Bergedorf, *A. Abh.*, 2, No. 3, 1920. ‖ *A.N.*, **209**, 269, 1919. ¶ *B.A.N.*, **1**, 79, 1922.
* *Magnitudes and Colours of Stars North of* $+80°$, Seares, Ross and Joyner, Washington, 1941.

TABLE XXV

IPv − HPv −0·14

HPv	4·5	5·0	5·5	6·0	6·5	7·0	7·5	8·0	8·5
C <·20	−·12(1)	−·08(1)	−·07(5)	·00(10)	·00(14)	−·03(17)	+·03(25)	·00(22)	−·10(1)
·20 < *C* <·90	−·02(1)	−·14(2)	−·05(5)	−·02(5)	−·02(12)	·00(35)	+·02(17)	+·09(11)	·00(5)
C >·90	+·01(4)	+·02(3)	−·01(5)	·00(8)	+·01(14)	+·03(25)	−·02(17)	−·17(02)	
All stars	−·02(6)	−·05(6)	−·04(15)	−·01(23)	·00(40)	·00(77)	+·02(59)	+·02(35)	−·01(6)

C	−·25	−·15	−·05	+·10	+·30	+·50
IPv <7·1	·00(2)	−·01(8)	−·01(6)	−·04(19)	−·06(12)	−·08(8)
IPv >7·1	+·02(4)	+·03(13)	·00(16)	·00(28)	+·03(23)	+·04(11)
All stars	+·02(6)	·00(21)	·00(22)	−·01(47)	·00(35)	−·01(19)

C	+·70	+·90	+1·10	+1·30	+1·50	+1·70
IPv <7·1	−·02(5)	+·02(18)	+·01(10)	−·05(11)	+·04(9)	+·02(4)
IPv >7·1	+·02(10)	+·01(25)	−·02(14)	+·03(9)	+·05(4)	
All stars	+·01(15)	+·01(43)	−·01(24)	−·01(20)	+·04(13)	+·02(4)

differences. It will be noticed that though the colour relation is slightly irregular for the brighter stars, there is on the whole no systematic colour difference between the *HPv* and *IPv* magnitudes, though there may be a small scale run of the order of $0^m.02$ per magnitude. The zero point difference at 7·0 seems to be $0^m.14$, 7·00 *HPv* being equivalent to 7·14 *IPv*.

The average value of *HPv* for this comparison is about 7·00. The corresponding value of *Pv′* is 7·20, so that the mean colour coefficient of the difference between *HPv* and *Pv′* will be about 0·13. The colour relation between *HPv* and *IPv* is not sufficiently definite to justify the carrying forward of the observed variability of the colour relation between *HPv* and *Pv′*. As a temporary expedient it was decided to try the effect of applying a straight colour correction of 0·14 *C* to the *Pv* and *Pv′* magnitudes.

The *Pv* magnitudes were corrected by 0·14 *C* and then compared with the standard magnitudes for the Pleiades and Praesepe. No additional correction for scale or colour could be detected. On the other hand, the relationship between *Pv* and Graff's visual magnitudes for the Hyades was found to be

$$m_{\text{Graff}} = 0{\cdot}867\,Pv + 0{\cdot}12\,C.I. + 1{\cdot}138.$$

The determinations of the zero correction were as follows:—

IPv − (*Pv* + 0·14 *C.I.*) =	+0·04	(Pleiades—Standard Magnitudes)
	+0·03	(Pleiades—Graff)
	+0·01	(Pleiades—*HPv*)
	+0·07	(Praesepe—Standard Magnitudes)
	0·00	(Praesepe—van den Bos)
	−0·05	(Praesepe—Potsdam)
	−0·08	(Praesepe—Graff)
	−0·17	(Praesepe—Bernheimer and Reimer)
	−0·04	(Praesepe—*HPv*)

$$IPv-(Pv+0\cdot14\ C.I.)=+0\cdot11 \quad \text{(Hyades—Potsdam—5 stars only)}$$
$$+0\cdot07 \quad \text{(Hyades—}HPv\text{)}$$
$$-0\cdot06 \quad (-30^\circ \text{ to } -35^\circ \text{ Zone})$$

(A correction of $-0^m\cdot20$ was applied to Graff's magnitudes for the Pleiades, which are stated to be on the Potsdam system, and a correction of $+0^m\cdot20$ to van den Bos's, which were based on Potsdam magnitudes reduced to "a normal scale" by a formula given by Hertzsprung. This normal scale differs from the Potsdam one at $7^m\cdot5$ by about $-0^m\cdot40$. The zero corrections found from the *HPv* magnitudes were corrected by $0^m\cdot14$.)

It was decided not to apply any zero correction to the *Pv* magnitudes until further observational data indicate that it is really necessary. Such further observational data are clearly necessary. It is hoped that it may be obtained by re-observing some of the Eros comparison stars whose magnitudes on the international scale have been determined by Seares, Sitterly and Joyner.*

It appears, then, that with the data available at present, the most probable reduction of the *Pg*, *Pv* magnitudes to the international system is given by the following formulæ:—

$$IPg = Pg - 0\cdot11\ Pv + 0\cdot880,$$
$$IPv = Pv + 0\cdot14\ C.I._{\text{Cape}},$$
$$C.I._i = 0\cdot86\ C.I._{\text{Cape}} - 0\cdot11\ (Pv - 8\cdot0).$$

Assuming that these formulæ hold also for the *Pg'*, *Pv'* magnitudes, and taking

$$C.I._i = 0\cdot86\ C.I._{\text{Cape}},$$

we get

$$Pg' = 1\cdot124\ IPg - 0\cdot14\ C.I._i - 0\cdot989,$$
$$Pv' = IPv - 0\cdot16\ C.I._i.$$

Substituting this value of *Pg'* in the relations between *Pg'* and *Pg*(*H*) and *Pg*(*h*) we get

$$Pg(H) = 1\cdot124\ IPg - 0\cdot07\ C.I._i - 0\cdot94 \quad (7 < m < 11),$$
$$Pg(h) = 0\cdot967\ IPg - 0\cdot21\ C.I._i + 0\cdot16 \quad (7 < m < 9),$$
$$= 1\cdot259\ IPg - 0\cdot21\ C.I._i - 2\cdot18 \quad (9 < m < 11).$$

TABLE XXVI

Variation of $C.I._i$ with the Measured Photovisual Magnitude

Sp. Type \ M_{vis}	6·5	7·0	7·5	8·0	8·5	9·0	9·5	10·0
B3			−·16					
B5				−·17				
B8			−·13	−·15	−·12	−·14	−·14	
B9		−·04	−·05	−·10	−·13	−·10	−·16	
A0	+·04	+·05	−·04	−·01	+·01	·00	−·07	−·13
A2		+·11	+·05	+·11	+·06	+·08	+·02	−·03
A3		+·22	+·12	+·17	+·17	+·14	+·12	
A5				+·19	+·19	+·20	+·11	+·02
F0	+·35	+·36	+·29	+·25	+·25	+·23	+·16	
F2		+·47	+·37	+·34	+·31	+·25	+·20	
F5	+·52	+·48	+·42	+·39	+·35	+·35	+·24	+·15
F8		+·51	+·54	+·45	+·45	+·31	+·38	+·18
G0	+·88	+·64	+·61	+·58	+·55	+·44	+·33	+·25
G5	+1·07	+1·04	+·96	+·83	+·77	+·71	+·54	+·42
K0	+1·32	+1·26	+1·13	+1·07	+·99	+·88	+·81	+·63
K2	+1·55	+1·45	+1·35	+1·23	+1·13	+1·03	+0·88	
K5	+1·68	+1·66	+1·53	+1·44	+1·30	+1·09	+0·88	
Ma			+1·56		+1·47			

* *Ap. J.*, 72, 311, 1930.

Variation of Colour Index with Magnitude.—The result of reducing the colour indices shown in Table VI to the international system by means of the formula

$$C.I._i = 0{\cdot}86\ C.I._{\text{Cape}} - 0{\cdot}11\ (Pv - 8{\cdot}0)$$

is shown in Table XXVI. Only the values found from more than five stars are tabulated. The change in colour index with magnitude is still marked, though now it is the early type stars for which this variation is least.

TABLE XXVII

Rate of Change of Colour Index with Magnitude

Sp. Type	$C.I._0$	$\Delta\ C.I./\Delta m$	$0{\cdot}15\ (C.I._0 + 0{\cdot}20)$
F0	0·27	0·07	0·07
F5	0·39	0·09	0·09
G0	0·58	0·12	0·12
G5	0·85	0·17	0·16
K0	1·06	0·19	0·19
K2	1·23	0·22	0·21

The rate of change of the colour index with magnitude is tabulated in Table XXVII. This rate of change is well represented by $0{\cdot}15\ (C.I._0 + 0{\cdot}20)$, where $C.I._0$ denotes the *C.I.* corresponding to $Pv = 8{\cdot}0$.

If the variability of the colour coefficient found in the comparison of the *HPv* and

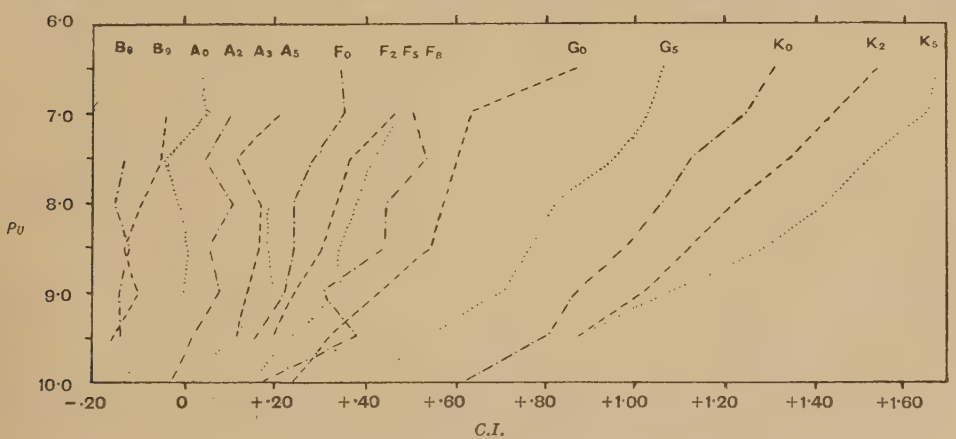

FIG. 2.—*Variation of Colour Index with apparent magnitude.*

Pv′ magnitudes be attributed to the *Pv′* magnitudes, this decrease of colour index with increasing magnitude will be still further accentuated.

Acknowledgments

There remains the pleasant task of acknowledging the assistance received during the course of this work. Like most work done at this observatory, it is not the results of the efforts of an individual but of those of a small team—in this case, due to war-time conditions, of a very small team most of whose members are busy with other tasks. Special mention should be made of Mr. G. W. Reed, M.Sc., who, before he left in 1940 to go on active service, had obtained and measured about one-third of the plates used

in this paper and about half of the plates for the −30° to −35° Zone, of Miss Strofield (now on active service) and Mr. R. P. de Kock who have shared the highly monotonous but very essential job of recording and reducing the microphotometer measures, and of Mr. A. Menzies on whom has fallen the task of completing the measuring and reduction of the zone plates, a task in which he is being assisted by Miss D. Booth.

We should also like to express our thanks to Dr. Schilt who procured us a suitable photronic cell and spare galvanometer for the photometer, and to Dr. Knox-Shaw, Dr. Redman, Dr. van Gent and Mr. Cousins who, having read a rough draft of this paper, made valuable suggestions for its improvement.

The Royal Observatory,
Cape of Good Hope:
1943 *May* 16.

NOTE ON A FURTHER SEARCH FOR POLARIZATION IN FRAUNHOFER LINES AT THE SUN'S LIMB

R. O. Redman

(Received 1943 October 18)

Summary

Further search by an improved method has failed to reveal any polarization in Fraunhofer lines at the Sun's limb. If such polarization exists it must be detectable only under exceptionally favourable observing conditions.

About two and a half years ago Dr Zanstra * showed that if atoms in the solar atmosphere act like classical oscillators, light within Fraunhofer lines should be polarized near the Sun's limb. Following this, the present writer † examined the solar spectrum at $\sin\theta = 0{\cdot}985$, but was able to find only a quite small amount of polarization in the line λ 4227, *Ca*I, a theoretically favourable case. The observed effect was about one-tenth of that predicted by theory, and was so small that some doubt was expressed as to its reality. Subsequently Zanstra ‡ showed that collision damping would reduce the predicted polarization very considerably, while recent work by the writer §, dealing with the spectrum of the Sun's limb, has suggested that the polarization would in effect be weakened by the roughness of the Sun's surface. This note deals with a short series of fresh observations, made by an improved method.

The same telescope and spectrograph were used as before. In front of the spectrograph slit was mounted a polarizing unit, consisting of a pinhole, a calcite crystal and a simple lens, of 6·4 cm. focal length. The pinhole was 0·8 mm. in diameter, and was about 25 cm. from the slit. By means of the crystal and the lens a double image of the pinhole, at about unit magnification, was thrown on the slit, the two images being polarized respectively parallel and perpendicular to the slit, and having a separation of between 5 and 6 mm. Immediately behind the slit was a field lens, of focal length 8·3 cm., necessary to make light from both pinhole images pass through the collimator lens. The latter worked at $f/32$, the telescope mirror at $f/18$, so that the collimator was properly filled by both light beams, although they used slightly different areas of the mirror. The diameter of the solar image was 5·0 cm., so that with the pinhole internally tangent to the limb, the observations were being made at $\sin\theta = 0{\cdot}985$. The polarizing unit was screwed to the slit face, with necessary adjustments provided for collimation, centring of images on the slit, and focusing. Over the slit was a photographic wedge, cutting down the intensity of one image relative to the other, so that the two spectra on reaching the focal plane of the spectrograph were of very nearly equal brightness. The chief advantages of this arrangement are that the two polarization components are photographed with exactly the same length of exposure, and at almost equal photographic densities, while they must come from exactly the same area of the Sun's surface at the same moment of time. Thus the observations are much more purely differential than before, and should be correspondingly more accurate. As an additional precaution, check photographs were made at the centre of the Sun's disk, where there should be no polarization, these being taken immediately after the limb photographs.

* *M.N.*, **101**, 250, 1941.
† *Ibid.*, 266.
‡ *Ibid.*, 273.
§ *M.N.*, **103**, 173, 1943.

A region covering between 20 and 25 A., including $H\gamma$, was first examined, using microphotometer tracings at magnification 40 : 1 (the spectrograph dispersion is here about 3·6 A./mm.). The only difference which could be detected between the spectra polarized respectively parallel and perpendicular to the limb was a slight change of line depth, averaging 0·012 in $\log I$ over 36 lines. Since, however, the photographs taken at the centre of the disk showed an average difference 0·008 in $\log I$ in the same sense, we have to conclude that this arises from some small systematic error of measurement, and not from anything on the Sun.

Next the region around λ 4227 was examined again. Measuring only maxima and minima on tracings at 100 : 1 magnification (spectrograph dispersion 3·1 A./mm.), the one plane of polarization gave line depths 0·008 in $\log I$ deeper than the other, exactly as at the centre of the disk. Attention was then directed specially to those places on the line profile where the earlier work showed a small positive polarization effect. The average effect now, however, amounted to only 0·002 in $\log I$, a quantity which is not significantly different from zero, and which is less than 2 per cent. of the theoretical effect.

Finally, measures were made at about 150 points over a range of 11·5 A. covering the *Mg* b line λ 5184 (tracings at 100 : 1, spectrograph dispersion 7·7 A./mm.). The average difference, taken without regard to sign, between the two polarization components was 0·006 in $\log I$, and only in the immediate neighbourhood of the line centre, where the measures were weakest, was there any suggestion of a positive effect. Here the difference amounted to 0·027 in $\log I$, but is not thought to be significant. This group of observations is rather less accurate than the others, partly on account of smaller spectrograph dispersion, and partly because war-time conditions compelled the use of stale panchromatic plates.

The apparent oscillation of the Sun's limb due to scintillation was between 7″ and 10″ for these observations. Better seeing appears to be rare in Pretoria in day-time. This amount of tremor, about 1 per cent. of the Sun's radius, does not seem sufficient to obliterate polarization at $\sin\theta = 0{\cdot}985$, were it present. De-polarization by the cœlostat and telescope mirrors, at the particular angles of incidence used, was examined directly and estimated to be less than 10 per cent.

The work confirms and strengthens the former conclusion that polarization in Fraunhofer lines is much smaller than predicted by Zanstra's original theory. Further search for any polarization is not considered to be worth while, except possibly in extraordinarily favourable circumstances, with a very powerful spectrograph and in really superb seeing.

Radcliffe Observatory,
Pretoria :
1943 *August.*

DOUBLE-STAR MEASURES

W. P. Hirst

(Communicated by H.M. Astronomer)

(Received 1943 May 3)

Most of the measures tabulated below were made with the 7-inch refractor at the Royal Observatory at Cape Town by kind permission of H.M. Astronomer, Dr. J. Jackson. Those marked with an asterisk were made at the Union Observatory by courtesy of the Union Astronomer, Dr. W. H. van den Bos. The 26-inch refractor was used.

The 7-inch telescope is by Merz and has a very good object-glass. The micrometer is by Repsold and the highest power available is about 300×. A reversing prism is fitted and was used from the beginning of 1942. The value of one revolution of the micrometer, determined by transits of circumpolar stars, is 46″·85.

The seeing at Cape Town is very variable. On some nights it is quite steady, but unfortunately such nights are not of very frequent occurrence. Estimates of the quality of the definition are given with each measure, the scale being: 1, just possible; 5, perfect. No estimates of magnitude differences are given.

The columns from left to right give: Name and ADS number if any; Right Ascension; Southern Declination (Equinox 1900); Date; Hour Angle; Position Angle; Distance; Seeing; Remarks. (Note: in the few cases in which northern stars appear a plus sign has been marked against the declination.)

	h m	° ′		h	°	″		
h 1957	0 16·8	23 34	40·912	+3·2	20·2	6·23	1	1*n*
ADS 302			40·953	+2·7	24·5	6·18	3	
			40·992	+2·7	21·9	5·95	3	
		Mean	40·952		22·2	6·12		3*n*
β_2 Tucn	0 27·0	63 31	41·645	−4·0	301·1	0·5(*e*)	3	1*n*
			43·099	+4·5	294·1	0·4(*e*)	3	1*n*
I 47	0 47·2	44 15	41·923	+2·0	8·2	1·36	2	1*n*
Stn. 3 A – B	0 47·3	23 09	40·942	+2·9	264·2	2·25	4	
ADS 716			40·995	+2·4	260·8	2·16	4	
			40·999	+2·7	260·3	2·20	1	
		Mean	40·979		261·8	2·20		3*n*
Σ 91	1 02·1	2 16	40·914	+0·9	320·7	4·22	2	
ADS 923			40·995	+3·5	317·3	4·45	3	
		Mean	40·854		319·0	4·33		2*n*
ζ Phœ	1 04·2	55 47	40·901	+1·2	242·5		1	
			40·995	+1·6	243·0	6·37	3	1*n*
I 27	1 11·6	69 21	40·992	+2·8	18·5	1·00	3	
			40·995	+2·6	20·7	1·36	4	
		Mean	40·993		19·6	1·18		2*n*
κ Tucn	1 12·0	69 24	40·901	+0·9	340·2	5·95	2	
			40·909	+1·0	340·5	5·76	2	
			40·953	+2·8	339·7	5·58	2	
			40·992	+2·8	341·2		2	
			41·013	+5·0	341·8	5·53	2	
		Mean	40·954		340·7	5·70		5, 4*n*
p Erid	1 36·0	56 45	40·912	+1·2	205·4	9·70	1	
Δ5			40·914	−0·4	206·4	9·56	3	
		Mean	40·913		205·9	9·63		2*n*

	h m	° ′		h	°	″		
θ Erid	2 54·5	40 42	40·958	+0·1	86·8	8·76	2	
			40·995	+2·2	86·8	8·52	2	
			41·013	+3·5	88·2	8·58	2	
			41·192	+5·1	88·9	8·32	1	
		Mean	41·039		87·7	8·54		4*n*
β 12	3 19·7	14 21	41·923	−1·0	278·9	1·92	1	1*n*
ADS 2523								
w Erid	3 49·3	3 15	41·923	−1·2	347·1	6·89	2	
ADS 2850			42·040	+0·4	347·9	6·70	1	
		Mean	41·981		347·5	6·80		2*n*
R 38	4 01·0	85 33	43·099	+1·5	246·9	1·69	3	1*n*
Howe 10	4 09·9	28 48	41·192	+3·0	42·2	2·34	1	
ADS 3069			41·266	+3·7	42·6	1·97	1	
		Mean	41·229		42·4	2·16		2*n*
Rumker 3	4 16·5	63 30	42·216	+3·5	3·1	4·03	3	
			43·096	+0·9	4·3		1	
			43·099	+1·5	4·0	3·98	3	
			43·110	+1·2	4·0	3·82	2	
		Mean	43·102		4·1	3·90		3, 2*n*
Σ 536	4 17·2	4 55	43·096	+1·7	173·0	1·50	2	
ADS 3163			43·099	+2·3	172·4	1·31	2	
			43·172	+3·7	170·9	1·31	1	
		Mean	43·022		172·1	1·37		3*n*
Rumker 4	4 22·3	57 18	41·192	+2·4	239·4	5·95	2	
			41·195	+3·3	240·2	6·28	2	
			43·096	+1·2	240·8	6·18	2	
			43·099	+1·7	239·6	5·90	3	
			43·110	+1·3	241·0	5·72	2	
		Means	41·193		239·8	6·11		2*n*
			43·102		240·5	5·93		3*n*
h 3683	4 38·1	59 08	42·216	+3·5	93·2	1·69	2	1*n*
κ Leps	5 08·6	13 04	40·942	−1·1	358·3	2·63	3	1*n*
ADS 3800								
Rigel	5 09·7	8 19	41·148	+1·3	206·7	9·24	2	
ADS 2823			41·211	+2·8	205·7	9·32	2	
		Mean	41·179		206·2	9·28		2*n*
H 26	5 30·6	4 26	40·928	−1·6	57·9	4·15	2	
ADS 4192			41·195	+1·5	59·0	4·03	1	
		Mean	41·061		58·5	4·08		2*n*
ι Orio	5 30·5	5 58	40·928	−2·3	140·6	10·96	2	
ADS 4193			41·167	+1·2	142·4	11·55	1	
			41·195	+2·5	142·0	11·57	1	
		Mean	41·097		141·7	11·36		3*n*
ζ Orio	5 35·7	2 00	41·126	+1·0	161·4	3·09	1	
ADS 4263			41·266	+2·7	156·7	2·96	1	
		Mean	41·196		159·0	3·03		2*n*
Jacob 3	5 45·4	14 31	41·182	+1·0	170·0	2·48	4	
ADS 4432			41·195	+1·5	167·8	3·05	2	
		Mean	41·188		168·9	2·76		2*n*
Δ 23	6 02·2	48 27	41·182	+1·2	86·3	2·18	4	
			41·195	+2·0	79·9	2·57	1	($\frac{1}{2}$ wt.)
			41·255	+2·0	82·4	1·97	4	
		Mean	41·214		83·5	2·17		3*n*

	h m	° ′		h	°	″		
Δ 39	7 01·7	59 02	42·216	+1·9	81·4	2·01	2	1*n*
γ Voln	7 09·6	70 20	41·118	−0·2	298·7	13·96	3	
			41·148	+0·5	299·4	13·54	1	
			41·182	+1·2	298·7	13·73	4	
			41·255	+1·8	297·8	13·96	4	
		Mean	41·176		298·6	13·80		4*n*
h 3949	7 14·7	30 37	41·182	+2·7	79·5	3·19	3	1*n*
Castor	7 28·2	+32 06	41·126	−0·5	198·9	4·12	1	(Low) 1*n*
ADS 6175			41·260		199·2		1	(,,)
h 3997	7 37·6	74 03	42·216	+1·5	118·8	1·85	2	1*n*
h 4073	8 14·5	27 04	41·423	+4·1	177·8	2·04	1	
			41·448	+4·4	176·9	1·66	2	
		Mean	41·436		177·4	1·85		2*n*
I 67	8 19·5	48 10	41·423	+4·3	138·2	0·96	2	
			41·488	+4·6	134·2	0·84	2	
		Mean	41·436		136·2	0·90		2*n*
β 205	8 28·8	24 16	41·423	+3·5	329	0·66	2	1*n*
ADS 6871								
β 208	8 34·8	22 19	41·423	+3·5	208·9	1·66	2	
ADS 6914			41·448	+3·5	203·1	1·66	1	
			43·096	−2·1	207·4	2·02	1	(½ wt.)
			43·099	−1·6	209·3	1·55	2	
		Means	41·436		206·0	1·66		2*n*
			43·098		208·7	1·71		2*n*
β 587	8 46·7	6 48	41·423	+4·1	126·2	1·22	1	
ADS 7050			41·448	+4·7	125·8	0·77	1	(½ wt.)
		Mean	41·431		126·1	1·07		2*n*
ω Leon	9 23·1	+ 9 30	41·225	−0·2	148·3	0·90	2	*
ADS 7390			41·257	−0·7	148·0	1·03	1	(½ wt.)
		Means	41·241		148·2	0·94		2*n*
			42·342	+2·5	154·5	1·12	2	1*n*
R 129	9 39·5	55 23	41·266	−0·7	295·6	3·19	1	
			41·448	+4·4	291·3	3·37	2	
		Mean	41·357		293·5	3·28		2*n*
I 13	10 07·0	68 12	41·318	+0·7	138·9	0·98	3	
			41·448		132·9	1·0(*e*)	1	(½ wt.)
			41·542	+4·3	135·8	0·7(*e*)	2	
		Mean	41·434		136·4	0·9		3*n*
β 175	10 07·6	26 46	41·225	−0·4	261·0	0·71	2	1*n* *
ADS 7683								
h 4310	10 10·3	83 36	41·318	+1·0	271·0	3·98	3	
			41·421	+4·2	268·6	4·17	2	
			41·542	+4·5	268·9	3·75	1	
		Mean	41·427		269·5	3·97		3*n*
γ Leon	10 14·5	+20 21	41·211	−1·2	119·6	4·69	2	
ADS 7724			41·257	−1·2	121·8	4·03	1	
			41·318	+0·2	122·6	4·36	3	
		Mean	41·262		121·4	4·39		3*n*
h 4306	10 16·0	64 11	41·318	+1·3	133·5	1·97	3	
			41·421	+4·4	133·8	2·06	2	
			41·463	+3·9	135·5	2·27	2	
			41·490	+5·2	135·3	2·08	2	
		Mean	41·423		134·5	2·09		4*n*

	h m	° ′		h	°	″		
s Velr	10 27·7	44 33	41·463	+3·3	218·5	13·61	1	
			41·545	+5·3	217·9	13·21	1	
		Mean	41·501		218·2	13·41		2*n*
Δ 97	10 39·4	60 39	41·148	−3·7	175·1	12·70	2	
			41·463	+3·3	173·1	12·37	2	
		Mean	41·306		174·1	12·54		2*n*
I 502	10 43·2	24 46	41·225	−0·7	35·9	0·5(*e*)	2	1*n* *
ADS 7918								
h 4423	11 11·8	45 20	41·318	+0·8	275·7	2·06	3	
			41·419	+3·8	275·7	2·14	2	
			41·499	+3·5	275·0	2·09	1	
			42·526	+3·8	274·6	2·06	2	
			42·578	+4·7	275·9		1	
		Means	41·412		275·5	2·10		3*n*
			42·552		275·2	2·06		2, 1*n*
α Cruc	12 21·0	62 33	41·192	−6·0	113·9	4·64	2	
			41·266	−2·8	116·3	4·64	1	
			41·423		117·4	4·83	1	
			41·608	+3·9	116·5	4·45	1	
		Mean	41·382		116·0	4·64		4*n*
γ Cent	12 36·0	48 25	41·266	−2·1	20·6	0·63	1	
			41·421	+1·9	17·9	0·82	4	
			41·509	+2·3	16·8	0·98	1	
			41·545	+3·9	17·4	0·80	2	
			42·523	+2·7	18·7	0·84	2	
			42·526	+2·8	12·9	0·71	2	
			42·531	+1·9	14·0	0·59	2	
		Means	41·435		17·4	0·81		4*n*
			42·527		15·2	0·71		3*n*
β 341	12 58·4	20 03	41·421	+2·0	133·7	0·82	3	
ADS 8757			41·509	+2·7	133·0	0·77	2	
			42·523	+3·0	129·3	0·82	3	
			42 531	+2·0	132·0	0·7(*e*)	2	
		Mean	41·465		133·4	0·80		2*n*
			42·527		130·6	0·76		2*n*
R 213	13 01·2	59 20	41·542	+4·3	22·4	0·70	3	
			41·645	+3·9	25·6	0·8(*e*)	4	
		Mean	41·594		24·0	0·75		2*n*
54 Virg	13 08·1	18 18	41·421	+0·1	35·5	5·20	2	
ADS 8824			41·509	+2·9	34·8	5·36	2	
			41·602	+4·1	31·9	5·50	1	(½ wt.)
		Mean	41·492		34·5	5·32		3*n*
Δ 141	13 35·3	54 03	41·542	+3·5	164·7	5·27	4	
			41·602	+4·2	162·6	5·34	1	
			41·608	+2·4	163·7		1	
			41·641	+3·9	166·0	5·29	1	
		Mean	41·598		164·3	5·30		4, 3*n*
Y Cent	13 47·7	35 10	41·542	+2·5	110·2	0·95	1	
			41·645	+3·5	112·3	1·22	3	
		Means	41·594		111·3	1·08		2*n*
			42·523	+2·7	113·3	0·94	2	
Σ 1788	13 49·7	7 34	41·542	+2·0	84·9	3·19	1	
ADS 9053			41·602	+4·2	85·6	3·28	1	
		Mean	41·572		85·3	3·23		2*n*

	h m	° ′		h	°	″		
R 227	13 49·8	53 39	42·531	+1·9	2·0	1·64	2	
			42·553	+1·9	3·2	1·62	1	
		Mean	42·542		2·6	1·63		2*n*
Δ 151	13 50·7	55 33	42·531	+2·3	46·1	22·6	3	1*n*
Δ 166	14 01·2	64 32	42·531	+2·4	232·2	15·8	2	1*n*
α Cent	14 32·8	60 25	41·182	−4·7	353·5	6·37	4	
			41·255	−6·0	353·2	6·18	4	
			41·266	−4·5	354·3	6·23	1	
			41·318	−4·5	354·4	6·47	3	
			41·419	−0·8	353·0	6·72	3	
			41·433	−1·8	355·3	6·51	3	
			41·545	+2·5	355·6	6·14	1	(½ wt.)
			41·556	+3·1	356·4	6·75	1	
			41·608	+2·2	358·6	6·63	2	
			42·216	−4·9	0·7	6·84	1	
			42·523	+2·4	0·6	7·07	3	
			42·526	+1·4	0·8	6·46	1	(½ wt.)
		Means	41·255		353·8	6·31		4*n*
			41·508		355·8	6·60		5*n*
			42·401		0·7	6·86		3*n*
μ Libr	14 43·8	13 44	41·421	+0·5	353·6	1·64	2	
ADS 9396			41·645	+3·1	353·9	1·71	4	
		Mean	41·533		353·8	1·68		2*n*
I 236	14 43·2	72 47	41·646	+4·4	106·9	1·57	2	1*n*
β 239	14 52·7	27 15	41·646	+4·0	331·9	0·96	3	1*n*
ADS 9453			42·523	+2·5	333·7	0·7(*e*)	2	1*n*
π Lupi	14 58·3	46 40	41·646	+3·3	75·3	1·43	4	1*n*
h 4753	15 11·6	47 30	41·646	+4·5	141·2	1·45	2	1*n*
h 4757	15 15·4	58 58	41·646	+4·3	56·8	1·13	2	1*n*
Lal 123 AB − C	15 27·2	24 09	41·638	+3·5	300·7	9·28	1	1*n*
ADS 9689								
λ 258 AB − C	15 55·4	57 30	41·638	+3·2	246·7	11·06	1	1*n*
Howe 82	15 57·4	32 48	41·638	+3·3	349·0	2·20	1	
			41·646	+2·0	345·5	2·25	5	
		Mean	41·642		347·2	2·23		2*n*
Σ 1998 A − B	15 58·9	11 06	41·602	+2·9	35·8	1·02	2	
ADS 9909			41·638	+2·0	37·3	1·08	1	
			41·645	+3·3	32·4	1·07	2	
		Mean	41·628		35·2	1·06		3*n*
Σ 1998 AB − C	15 58·9	11 06	41·602	+3·0	54·0	7·47	2	
ADS 9909			41·638	+2·1	55·2	6·84	1	
			41·645	+3·4	54·1	7·22	2	
		Mean	41·628		54·4	7·18		3*n*
β 1117	16 50·8	22 59	41·646	+3·1	292·1	0·82	2	1*n*
ADS 10265								
h 4931	17 11·8	59 20	42·515	−3·2	255·8	0·8(*e*)	2	1*n*
Melb. 4 A − B	17 12·8	34 53	41·448	−2·7	299·7	1·90	2	
			41·463	−2·8	300·9	1·87	1	
			41·490	−2·9	298·6	1·94	1	
			41·509	−2·0	300·2		1	
			41·712	+3·3	301·0	2·15	1	
			42·515	−3·4	297·3	1·80	3	
			42·523	−2·4	297·8	1·99	3	
			42·526	−2·7	297·0	1·94	4	
			42·531	−3·2	296·2	1·82	2	
			42·553	−1·9	296·6	1·99	1	
			42·687	+2·3	297·6	2·13	1	*
		Means	41·524		300·1	1·96		5, 4*n*
			42·556		297·1	1·94		6*n*

	h m	° ′		h	°	″		
Melb. 4 A – C	17 12·8	34 53	41·463	−2·6	133·1	31·95	1	1*n*
			42·523	−2·2	133·1	31·95	3	1*n*
Howe	18 24·5	33 03	42·687	+0·6	193·0	3·27	1	1*n* *
λ 361	18 43·1	33 42	42·687	+0·6	230·7	1·10	1	1*n* *
I 119	19 34·0	59 14	42·687	+0·7	164·5	1·30	1	1*n* *
h 5140	19 40·4	65 09	42·687	+0·6	260·7	1·67	1	1*n* *
Δ 227	19 44·7	55 14	40·901	+5·3	149·4	22·90	2	
			40·928	+6·3	147·7	23·32	1	
			40·934	+6·3	149·6	23·57	4	
		Means	40·921		148·9	23·26		3*n*
			41·602	−1·2	149·8	23·24	2	1*n*
I 1040	19 48·3	55 24	42·687	+0·5	194·8	1·43	1	1*n* *
Stn. 64	20 10·6	32 55	42·687	+0·4	121·6	2·18	1	1*n* *
Gls. 259	20 25·2	41 14	42·687	+0·6	156·5	3·63	1	1*n* *
Rumker 26	20 43·3	62 48	42·687	+0·7	268·2	2·46	1	1*n* *
β 763	20 17·1	42 45	42·687	+0·5	229·2	0·89	1	1*n* *

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A METHOD OF APPLYING DIFFERENTIAL CORRECTIONS TO THE ELEMENTS OF DOUBLE STAR ORBITS

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Summary

An approximate arithmetical method is given for applying differential corrections to the elements of the orbit of a double star. The method, which is much less laborious than the "least squares" method, is applied to an example.

The usual procedure of deriving differential corrections to the elements of double star orbits by the Method of Least Squares has been criticised by van den Bos * on the grounds that:

(1) the result obtained is hardly worth the work involved;

(2) elements that make the sum of the squares of the residuals a minimum are not necessarily the most probable.

In the same circular he described a graphical method based on the residuals in position angle only, and applicable to fairly open orbits. He also dealt with the case of the long, narrow apparent orbit in which the residuals in distance become of greater importance, but it is not proposed to consider this type of orbit in the present paper.

Briefly, the van den Bos method consists of plotting the residuals in angle as ordinates against any convenient abscissæ (the mean anomaly, or simply the serial number of the measure are suggested) and comparing this graph in turn with the graphs of the differential coefficients of the equation of condition in angle plotted against the same abscissæ. After each comparison the residual curve is corrected differentially for a change in the element concerned, of such magnitude as to remove as far as possible any systematic resemblance between the residual curve and the coefficient curve. The residual curve is then compared with the next coefficient curve and again corrected, and the procedure is repeated till no further resemblance with a coefficient curve can be detected.

The method is quick and involves no other calculation than the computing of the various differential corrections, once the coefficients and residuals have been computed from the preliminary elements, but it needs a good deal of expert judgment in making the comparisons. It is seldom that the measures available are of such accuracy that the residual curve follows the shape of any of the coefficient curves at all closely—when the preliminary orbit is reasonably accurate—and the comparison usually involves the detection of maxima and minima in the curve and the comparison of their position and magnitude with those of the coefficient curves. Generally the two curves will resemble each other at some points and not at others, and it is one of the great advantages of the method that the effect of each correction on every individual residual can be watched, and care taken at each step to see that the more reliable measures are given the greater weight.

When the residuals are large and irregular, however, the comparisons become very difficult and for such computers as prefer a more rigid method and one involving less in the way of personal judgment hitherto only the laborious Method of Least Squares has been available. In view of the notorious inaccuracy of double star measures this method, as van den Bos remarks, is far too elaborate to justify its use except where a very large number of measures is available.

The method to be described in the present paper consists entirely of arithmetical

* *U.O. Circ.*, 98, 1937.

computation and eliminates the factor of personal judgment except in the allocation of weights. It is based on the van den Bos method and may, when applied in one way, be said to be practically an arithmetical version of it. At the same time it is much simpler and less laborious than the Method of Least Squares.

The principle can best be explained by an example. Consider the coefficient $\partial\theta/\partial e$. This function is zero at periastron and apastron; it is positive from periastron to apastron in the direction of motion and negative in the other half of the orbit. Thus if the preliminary value assigned to e is too small there will, on the average, be an excess of positive residuals in the half of the orbit after periastron as compared with those in the half preceding periastron. If correct weights are given to the individual measures, a difference between the average of the weighted residuals in the two halves of the orbit on either side of the line of apsides is an indication that the eccentricity requires correcting; and the sense and magnitude of the required correction can evidently be determined by comparison with the difference of the averages of the corresponding weighted differential coefficients in the same halves of the orbit.

This assumes that the difference is unaffected by possible errors in the other elements, which in general will be the case. In the open type of orbit under consideration, however, the effect will usually be small unless the period is much in error. The differential coefficients of i and ω always have the same mean value over any range of 180° of position angle, so that the difference of the mean values in any two halves of the orbit vanishes; while the coefficient of T will usually be a minimum (or maximum if the angles decrease with the times) in the neighbourhood of periastron, and unless the values of the function are very unsymmetrical with respect to the line of apsides it will affect both sides roughly to the same extent. An error in the node, of course, effects all the angles equally.

Naturally, if the measures are very irregularly spaced round the orbit, the average of the values of a coefficient corresponding to the individual measures over a given arc may differ appreciably from the mean value of the coefficient considered as a continuous function. In this case errors even in i and ω may affect the correction to e, though usually not to any great extent.

It is evident that corrections to T, i and ω can be derived in the same way as the correction to e in the above example, and similar considerations show that an error in an element will not in general interfere with the correction to another to any serious extent, though it may do so in particular cases.

The correction to T will be obtained by taking the difference between the mean of the weighted residuals in the half of the orbit containing the smaller distances and that containing the larger.

For i and ω, the mean of the weighted residuals in one pair of opposite quadrants is subtracted from that of the residuals in the remaining pair, the quadrants being in position angle Ω to $\Omega+90°$; $\Omega+90°$ to $\Omega+180°$, etc. for i; and $\Omega+45°$ to $\Omega+135°$; $\Omega+135°$ to $\Omega+225°$, etc. for ω.

If measures covering more than a complete revolution are available, the period may be corrected similarly by comparing the means of the weighted residuals in the overlapping parts of the orbit, or by dividing the entire observed arc into two roughly equal parts and proceeding in a similar way.

As already mentioned, however, corrections to any element obtained in this way will be somewhat affected by errors in the other elements, in some cases seriously, and this difficulty has to be dealt with before the method can be trusted to yield reliable results.

One way of doing this is to follow the procedure used by van den Bos in his graphical method; that is, to work out the correction to one element, adjust the residuals differentially for this correction, then correct the next element and so on. After all the elements have been corrected in this way, the whole procedure is repeated until no further adjustment is required.

In many cases the second approximation is as close as the quality of the material justifies going, but in certain instances peculiarities of the orbit or the distribution of the measures may demand many trials before satisfactory corrections are obtained. For this reason the following method is preferable.

Write $M_{ab}(R)$ for the mean of the weighted residuals between position angles a and b and $M_{ab}(P)$, $M_{ab}(T)$, etc., for the means of the corresponding weighted coefficients of P, T, etc., between the same angles. Then the method of correcting e described above, ignoring the effect of errors in the other elements, will be expressed by the equation:

$$\{M_{pa}(e) - M_{ap}(e)\}\Delta e = M_{pa}(R) - M_{ap}(R), \qquad (1)$$

p being the position angle at periastron and a that at apastron. Allowing for the effect of the errors in the other elements this equation becomes:

$$\{M_{pa}(e) - M_{ap}(e)\}\Delta e + \{M_{pa}(P) - M_{ap}(P)\}\Delta P + \text{etc.} = M_{pa}(R) - M_{ap}(R), \qquad (2)$$

that is, the differences of the means (which may be termed "mean differences" for brevity) of the other coefficients between the angles p, a and angles a, p, multiplied by the required corrections to the elements, must be included on the left-hand side of the equation.

Four similar equations can be formed by taking mean differences of coefficients and residuals between the angles used for correcting each of the other elements, and the solution of the resulting five equations gives the values of the corrections directly. Ω is then corrected from the mean of the adjusted residuals, and a from the more reliable distances as usual.

The work involved, after computing the residuals and coefficients from the preliminary elements, consists of working out 30 mean differences and solving 5 simultaneous equations—a far smaller amount of work than would be involved in a least squares solution.

The method will be illustrated by applying it to the orbit of A.417 (A.D.S. 16497). The later (from 1927) measures used were kindly supplied by Dr. van den Bos. The earlier ones were taken from A.D.S. Catalogue. As the only elements then available were Aitken's 1918 figures which were based on very few measures and were probably not accurate enough for the application of differential corrections, a fresh set of elements was computed as follows:—

P	22·00 years	ω	268°·6	A	+0·0417
T	1917·64	i	43°·6	B	−0·1433
e	0·335	Ω	18°·2	F	+0·1955
a	0″·2045			G	+0·0603

Aitken's closely similar 1931 orbit was only found after the computation was completed. Table I gives the measures used, the residuals in angle and distance relative to the preliminary orbit (marked with suffix p), and the residuals relative to the corrected elements (marked with suffix c). The weights assigned are also included.

The coefficients were computed from the following formulæ:—

$$S = AG - BF; \qquad R = n\cos\phi, \quad \text{where} \quad \sin\phi = e;$$

$$\frac{\partial\theta}{\partial T} = -\frac{RS}{\rho^2}; \qquad \frac{\partial\theta}{\partial P} = \frac{t-T}{P}\cdot\frac{\partial\theta}{\partial T};$$

$$\frac{\partial\theta}{\partial e} = \frac{57{\cdot}3}{R}\left(X\frac{\partial Y}{\partial e} - Y\frac{\partial X}{\partial e}\right)\cdot\frac{\partial\theta}{\partial T};$$

$$\frac{\partial\theta}{\partial i} = -\tfrac{1}{2}\tan i\sin 2(\theta - \Omega);$$

$$\frac{\partial\theta}{\partial\omega} = \cos i + \sin i\tan i\sin^2(\theta - \Omega).$$

TABLE I

Date	θ_0	$\Delta\theta_p$	$\Delta\theta_c$	ρ_0	$\Delta\rho_p$	$\Delta\rho_c$	Wt.	n	Obs.
	°	°	°	″	″	″			
1902·64	61·0	+ 0·2	− 0·3	·19	−·02	−·01	3	4	A
03·66	73·5	+ 1·6	+ 1·1	·19	−·02	−·01	3	5	A
04·58	84·8	+ 2·6	+ 2·0	·22	+·02	+·02	3	2	A
05·59	94·6	+ 0·7	+ 0·3	·20	·00	·00	3	3	A
06·51	106·1	+ 1·4	+ 1·1	·20	·00	·00	3	3	A
07·70	118·0	− 0·7	− 1·0	·20	·00	·00	2	1	A
08·66	130·6	+ 0·5	+ 0·5	·19	−·01	−·01	3	3	A
09·72	144·9	+ 2·6	+ 2·8	·17	−·03	−·03	3	3	A
10·72	156·9	+ 3·5	+ 3·9	·20	−·01	·00	3	3	A
11·84	169·4	+ 3·6	+ 4·3	·22	+·01	+·01	3	3	A
12·64	177·5	+ 2·8	+ 3·8	·19	−·01	−·02	3	3	A
14·60	196·0	− 3·5	− 1·6	·18	·00	·00	3	4	A
15·62	207·5	− 9·5	− 7·0	·16	+·01	+·01	3	3	A
16·68	230·0	−15·4	−12·6	·14	+·02	+·03	2	3	A
17·70	290·5	+ 1·4	+ 1·3	·12	+·02	+·03	2	4	A
18·56	330·9	+ 4·5	+ 1·6	·13	+·02	+·02	2	3	A
18·59	323·4	− 3·9	− 7·1	·16	+·05	+·05	1	1	V.Bs.
19·66	355·2	− 1·9	− 5·0	·15	·00	·00	2	2	A
20·54	16·4	+ 3·5	+ 0·9	·18	+·01	+·01	3	2	A
20·89	20·3	+ 2·3	− 0·3	·20	+·02	+·02	2	1	V.Bs.
21·56	29·3	+ 2·6	+ 0·2	·19	·00	·00	3	3	A
22·62	41·5	+ 2·4	0·0	·19	−·02	−·01	3	3	A
23·64	50·2	0·0	− 2·1	·22	+·01	+·01	2	2	A
24·55	64·3	+ 4·4	+ 2·2	·22	+·01	+·01	2	1	A
25·66	72·2	+ 0·3	− 1·9	·19	−·02	−·01	3	3	A
27·38	93·1	+ 1·7	− 0·6	·21	+·01	+·01	3	3	B
27·78	94·4	− 1·7	− 3·9	·19	−·01	·00	2	1	A
28·81	112·3	+ 4·0	+ 1·9	·25	+·05	+·06	3	2	B
28·81	109·6	+ 1·3	− 0·8	·24	+·04	+·05	3	2	ϕ
28·83	113·5	+ 5·0	+ 2·9	·22	+·02	+·03	3	2	A
29·46	117·5	+ 1·6	− 0·6	·21	+·01	+·02	3	4	V
29·78	125·2	+ 5·5	+ 3·3	·20	·00	·00	3	4	B
30·47	124·6	− 3·3	− 5·2	·20	·00	·00	3	5	V
30·83	129·3	− 2·7	− 4·7	·20	·00	·00	3	2	A
30·84	133·2	+ 1·1	− 0·9	·20	·00	·00	3	3	B
31·54	133·8	− 6·5	− 8·0	·19	−·01	−·01	2	4	V
31·70	143·8	+ 1·7	+ 0·2	·18	−·02	−·02	3	2	A
31·91	148·2	+ 3·8	+ 2·2	·17	−·03	−·03	3	4	B
32·42	149·6	− 0·5	− 1·9	·22	+·01	+·02	3	4	V
32·79	166·2	+12·0	+10·7	·20	−·01	·00	0	1	ϕ
32·85	153·8	− 1·1	− 2·4	·19	−·02	−·01	3	4	B
32·85	151·2	− 3·7	− 5·0	·18	−·03	−·02	3	3	A
33·47	165·8	+ 4·1	+ 3·0	·20	−·01	−·01	3	4	V
33·79	165·4	+ 0·1	− 0·8	·19	−·02	−·02	3	4	B
33·80	162·4	− 2·9	− 3·9	·19	−·02	−·02	3	3	A
34·49	174·9	+ 1·9	+ 1·1	·20	·00	·00	3	5	V
34·72	178·3	+ 2·7	+ 2·0	·23	+·03	+·03	1	4	Wil (I)
34·73	174·6	− 1·2	− 1·9	·18	−·02	−·02	3	3	A
35·50	184·6	− 0·2	− 0·8	·19	·00	·00	3	5	V
35·88	189·9	+ 0·4	− 0·1	·20	+·01	+·01	3	4	V
35·88	193·4	+ 3·9	+ 3·4	·19	·00	·00	3	3	B
36·50	198·6	+ 0·7	+ 0·2	·20	+·02	+·02	3	4	V
37·48	220·6	+ 6·3	+ 5·7	·19	+·03	+·04	2	4	V
37·48	232·0	+17·7	+17·1	·17	+·01	+·02	0	1	Wil (I)
37·53	214·0	− 1·3	− 1·9	·17	+·02	+·02	3	4	B
38·53	251·8	+11·5	+ 8·8	·16	+·04	+·05	2	5	V
38·84	282	+31·0	+26·9	·13	+·02	+·02	1	2	B
39·75	211·2	−80·2	−89·0	·25	+·15	+·16	0	4	Wil (I)
39·85	313	+16·9	+ 7·8	·14	+·04	+·05	2	3	B
40·82	341	+ 5·7	− 2·3	·14	+·02	+·01	3	3	B

(I) indicates that the interferometer was used.

As the calculated angles and distances for computing the residuals were obtained by the use of the Thiele-Innes constants and the tables of X and Y (published with *U.O. Circ.*, 71, 1926), the above formulæ contain no variables other than those already obtained in the course of that computation.

The coefficients and residuals in angle were then tabulated against the computed angles, and the angles between which the various mean differences were to be taken were marked. The points of division were, of course, those that would have been used in computing the corrections separately by the method of successive approximations, viz.:

For P 16°·2, *i.e.* about half-way round the observed arc.
„ T 16°·2 and 196°·2, *i.e.* 90° before and after periastron.
„ e 106°·2 and 286°·2, *i.e.* periastron and apastron.
„ i 18°·2, 108°·2, 198°·2 and 288°·2, *i.e.* ☊, ☊ +90°, etc.
„ ω 63°·2, 153°·2, 243°·2 and 333°·2, *i.e.* ☊ +45°, ☊ +135°, etc.

Reference to Table I shows that if the above angles are arranged in order of magnitude there will be no measures between several pairs of them. In fact, when all the dividing points are marked they break up the residuals and coefficients into only 17 groups. As, in computing the means, the individual figures in any one group will either be all included or all omitted together, it will obviously save a lot of repeated addition to sum the weighted residuals and coefficients in each group at the start and to use these sums in computing the 30 mean differences. The sums of the groups are shown in Table II. The first column gives the points of division, the second the sums of the weights and the remaining columns the sums of the weighted coefficients and residuals.

The coefficients of P and T are expressed in units of 0·1 year, that of e in units of 0·01 and those of i and ω in units of 1°.

TABLE II

Division Points	ΣWt.	$\Sigma\frac{\partial\theta}{\partial P}$	$\Sigma\frac{\partial\theta}{\partial T}$	$\Sigma\frac{\partial\theta}{\partial e}$	$\Sigma\frac{\partial\theta}{\partial i}$	$\Sigma\frac{\partial\theta}{\partial\omega}$	ΣR
18·2	3	+ 2·19	− 3·24	+ 2·07	− 1·41	+ 3·06	+ 0·60
63·2	12	+ 7·83	−13·98	+ 3·72	− 3·33	+15·33	+18·00
106·2, 108·2	8	+ 3·75	− 9·23	− 3·49	+ 2·65	+10·05	+ 7·90
153·2	9	+ 2·70	−10·05	− 7·14	+ 3·72	+ 8·43	+29·70
196·2, 198·2	6	+ 1·14	−10·56	− 5·82	− 0·90	+ 4·56	−39·00
243·2	2	+ 0·30	− 6·94	− 1·70	− 0·94	+ 2·16	−30·80
286·2, 288·2	5	− 0·49	−20·48	+ 2·70	+ 1·40	+ 6·12	+ 7·90
333·2	5	− 1·01	− 8·87	+ 4·90	+ 0·91	+ 3·86	+ 6·70
16·2, 18·2	12	− 3·13	−14·18	+10·06	− 3·15	+ 9·93	+28·40
63·2	8	− 3·84	− 9·17	+ 2·85	− 2·53	+10·08	+ 2·60
106·2, 108·2	35	−23·72	−40·68	−12·24	+ 8·87	+44·59	+39·50
153·2	31	−27·41	−35·91	−25·83	+10·69	+27·26	+ 6·60
196·2	3	− 3·69	− 4·32	− 2·82	+ 0·06	+ 2·19	+ 2·10
198·2	7	−15·02	−16·19	− 6·75	− 2·22	+ 5·94	+31·70
243·2	1	− 3·60	− 3·76	− 0·78	− 0·45	+ 1·14	+31·00
286·2, 288·2	2	− 9·50	− 9·42	+ 0·52	+ 0·26	+ 2·72	+33·80
333·2	3	− 9·96	− 9·48	+ 2·82	+ 1·41	+ 3·09	+17·10
16·2							

Equations of the form of equation (2) were now constructed by taking mean differences in turn between the five sets of angles given above. For example, the coefficient of ΔP in the 5th equation was computed as follows:—

$$\Sigma\frac{\partial\theta}{\partial P}\left\{\begin{matrix}63\cdot2 \text{ to } 153\cdot2 \text{ and}\\ 243\cdot2 \text{ to } 333\cdot2\end{matrix}\right\} = -29\cdot27; \qquad \Sigma\text{Wt} = 73; \qquad \text{Mean} = -\cdot401$$

$$\text{„} \quad \left\{\begin{matrix}153\cdot2 \text{ to } 243\cdot2 \text{ and}\\ 333\cdot2 \text{ to } 63\cdot2\end{matrix}\right\} = -54\cdot19; \qquad \text{„} = 79; \qquad \text{„} = -\cdot686$$

$$\Delta \text{ Means} = +\cdot285$$

In this way the following equations were obtained:—

$$\begin{array}{rrrrrr}
+1{\cdot}307\Delta P - & {\cdot}264\Delta T + & {\cdot}220\Delta e - & {\cdot}085\Delta i + & {\cdot}023\Delta\omega = & -1{\cdot}870 \\
+ {\cdot}877 & +1{\cdot}493 & - {\cdot}050 & +{\cdot}145 & +{\cdot}115 & = - {\cdot}650 \\
+ {\cdot}285 & - {\cdot}427 & +1{\cdot}246 & -{\cdot}340 & +{\cdot}041 & = +1{\cdot}530 \\
- {\cdot}409 & + {\cdot}080 & - {\cdot}474 & +{\cdot}590 & +{\cdot}049 & = + {\cdot}665 \\
+ {\cdot}285 & - {\cdot}129 & + {\cdot}246 & -{\cdot}034 & +{\cdot}397 & = + {\cdot}442
\end{array}$$

The solution of these equations gave the following values for the differential corrections *:—

ΔP	$-0{\cdot}16$ years	Δi	$+1^\circ{\cdot}5$
ΔT	$+0{\cdot}04$,,	$\Delta\omega$	$+1^\circ{\cdot}2$
Δe	$+0{\cdot}021$		

These corrections were then applied differentially to the sums of the groups of weighted residuals in Table II, after which the sum of all the weighted residuals was found to be $-5^\circ{\cdot}87$. Dividing this by 152, the sum of the weights gives $-0^\circ{\cdot}03$ as the required correction to Ω which can be regarded as negligible.

Finally, comparison of all the computed distances greater than $0''{\cdot}18$ with the corresponding observed distances gave the most probable value of a as $0''{\cdot}200$.

The corrected elements are therefore:—

P	21·84 years	i	$44^\circ{\cdot}7$	A	$+0{\cdot}0437$
T	1917·68	ω	$269^\circ{\cdot}8$	B	$-0{\cdot}1353$
e	0·356	Ω	$18^\circ{\cdot}2$	F	$+0{\cdot}1901$
a	$0''{\cdot}200$			G	$+0{\cdot}0620$

The residuals from these elements are given in Table I in the columns headed $\Delta\theta_c$ and $\Delta\rho_c$. The fit seems to be as good as could be expected for such a close pair. Wilson's last interferometer measure (1939·75) appears to be almost exactly 90° in error, and his 1937·48 measure is also rather widely out. This fact seemed to justify the low weight given to the 1934·72 measure by the same observer using the same method. Van den Bos's 1938·84 measure also has a large residual, but the distance was then only a tenth of a second which means only a slight elongation in a $26\frac{1}{2}$-inch refractor. The fact that the residuals of the preceding and following measures (ignoring the obviously erroneous 1939·75 measure) were also positive and fairly large seems to demand, however, that the measure be given some weight.

This orbit illustrates the point that was made earlier in the paper about the extra work involved in applying the successive approximation method in certain peculiar cases. In this instance, the line of nodes is nearly at right angles to the line of apsides and the measures on the periastron side of the line of nodes are comparatively few and of low weight.

Now in correcting e the mean difference is taken of the residuals on the two sides of the line of apsides. In applying the successive approximation method it is assumed that subsequent corrections to other elements will only change this mean difference to a small extent. But the correction to i is obtained from the mean difference of opposite pairs of quadrants, the quadrants in this case being practically those defined by the line of nodes and the line of apsides. If each of these quadrants contained evenly distributed measures of about equal weight, the mean of the values of $\partial\theta/\partial i$ in the two quadrants on one side of the line of apsides would be about equal and of opposite sign, and so would almost cancel each other when the correction to e was computed. Actually the total weight in the quadrants on the apastron side of the line of nodes is greater than that on the periastron side so that the values of $\partial\theta/\partial i$ on one side of the line of apsides do not even approximately cancel out, and if Δi is appreciable, its subsequent correction will change the mean difference of the residuals from which Δe was computed.

* The values of ΔP, ΔT, etc., apparently do not satisfy the simultaneous equations; this is explained by the choice of units.—Ed.

The result is that many successive approximations will be required before the mean differences from which Δe and Δi are computed both vanish. The simultaneous equation method, on the other hand, involves no more computation in this case than in any other, and it was for this reason that it was stated to be preferable to the method of correcting by successive approximations.

In the graphical method, the computer would be warned by the relative position of the $\partial\theta/\partial e$ and $\partial\theta/\partial i$ curves; and an experienced computer would be able to avoid the many successive adjustments by estimating corrections to both elements simultaneously, mentally combining the two coefficient curves. If the residuals in a critical part of the orbit are very irregular, however, it certainly needs an experienced and skilful computer to do this safely.

In conclusion I should like to express my gratitude to Dr. W. H. van den Bos for much helpful advice and criticism as well as for his courtesy in supplying the measures of A. 417 and copies of the X, Y tables.

THE ORBIT OF MELB. 4 AB

W. P. Hirst

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The most recently published orbit of the two brighter components of this well-known triple star appears to be that computed by Voûte *, which gave the following elements:—

P	42·2 years	i	129°·6	A	+0·283
n	8°·53	Ω	130°·2	B	+1·290
T	1933·68	ω	64°·0	F	+1·452
e	0·551			G	−0·926
a	1″·83				

These elements were based on more than a complete revolution but there were few measures available earlier than 1892, and of these only two were close to the 1891 periastron. Moreover, most of the early measures were by northern observers, by few of whom the pair could ever be seen at an altitude exceeding 20°. Since the computation of Voûte's orbit many more measures have been made, and in particular the periastron of 1933 was closely followed by Voûte himself at Lembang and by van den Bos and Finsen at Johannesburg.

From these later measures it appears that Voûte's eccentricity is too small and that some of the other elements are also capable of being improved slightly.

Recomputation of the elements gave the following results:—

P	42·09 years	i	128°·2	A	+0·2850
n	8°·552	Ω	133°·0	B	+1·2200
T	1933·77	ω	67°·5	F	+1·4623
e	0·574			G	−0·9357
a	1″·82				

The table below gives the measures used and the residuals O − C.

Measures of Melb. 4 AB

Date	θ_0	O − C	ρ_0	O − C	n	Aperture (ins.)	Observer
	°	°	″	″			
1877·53	226·3	+ 0·2	1·68	+0·04	1	11	Howe
77·64	224·4	− 1·1	1·97	+0·34	1	11½	Russell
88·72	147·5	+ 3·7	1·89	+0·76	1	12	β
89·43	134·1	− 1·0	1·35	+0·32	3	12	β
89·63	131·9	− 0·3	0·97	−0·02	1	11½	Pollock
90·60	122·0	+ 7·5	0·82	+0·04	2	11½	Sellors
91·53	81·2	− 2·4	0·51	−0·06	3	12	β
92·38	24·4	−11·9	0·58	+0·08	4	36	β
93·55	348·3	− 0·7	0·71	−0·06	5	11½	Sellors
94·56	334·5	+ 2·6	1·30	+0·22	5	36	Barnard
94·57	331·8	0·0	0·88	−0·20	7	11½	Sellors
95·60	321·7	+ 0·4	0·91	−0·41	2	15½	Comstock
95·62	322·2	+ 1·1	1·43	+0·10	3	11½	Sellors
95·74	321·4	+ 1·2	0·99	−0·36	1	15½	See
96·44	315·3	+ 0·1	1·46	−0·04	3	12, 36	A

* *B.A.N.*, 2, 181, 1924.

Date	θ_0	O – C	ρ_0	O – C	n	Aperture (ins.)	Observer
	°	°	″	″			
1896·46	315·4	+ 0·3	1·61	+0·10	3	5	Scott
96·59	315·8	+ 1·5	1·87	+0·34	4	11½	Sellors
96·60	314·9	+ 0·7	1·26	−0·27	1	15½	Comstock
97·39	307·0	− 2·8	1·69	+0·03	1	24	See
97·46	309·1	− 0·3	2·00	+0·33	3	12	A
97·47	308·8	− 0·6	1·80	+0·13	5	5	Scott
97·52	310·2	+ 1·1	1·86	+0·18	4	12	Lehmann
97·63	305·4	− 3·1	1·61	−0·09	2	15½	Comstock
98·35	303·8	− 1·4	1·99	+0·20	4	12, 36	A
98·60	305·6	+ 1·5	1·51	−0·31	2	15½	Comstock
98·62	305·1	+ 1·1	1·92	+0·10	3	11½	Sellors
99·38	300·2	− 0·7	1·83	−0·08	4	12, 36	A
99·42	299·1	− 0·8	1·78	−0·13	5	18	Doolittle
99·58	297·5	− 2·6	1·77	−0·16	3	15½	Comstock
99·68	300·7	+ 1·0	2·19	+0·25	3	11½	Sellors
1900·42	299·0	+ 2·1	1·95	−0·05	3	8	Tebbutt
00·49	295·6	− 1·1	1·91	−0·09	3	12, 36	A
00·53	299·0	+ 3·5	2·16	+0·15	4	18	Lunt
00·60	294·2	− 2·1	2·02	+0·01	3	18	Doolittle
01·77	291·2	− 1·1	2·06	−0·01	3	6	Doberck
02·36	292·1	+ 1·7	2·29	+0·20	3	18	I
02·44	288·9	− 1·2	1·87	−0·23	3	12, 36	A
02·49	290·0	+ 0·1	2·57	+0·47	5	8	Tebbutt
02·57	288·6	− 1·1	1·72	−0·38	2	15½	Comstock
03·55	283·0	− 3·6	1·93	−0·21	2	15½	Comstock
03·56	286·1	− 0·4	2·07	−0·07	3	12, 36	A
03·62	283·3	− 3·0	2·03	−0·11	9	18	Doolittle
03·66	287·1	+ 0·9	2·25	+0·11	5	5	Scott
04·62	283·3	+ 0·1	1·69	−0·47	1	15½	Comstock
04·63	282·8	− 0·4	2·03	−0·13	1	36	A
05·62	279·3	− 0·9	2·38	+0·22	3	8	Tebbutt
05·63	280·1	0·0	2·30	+0·14	1	36	A
05·64	281·5	+ 1·4	2·04	−0·12	4, 3	6	Doberck
06·46	276·9	− 0·7	2·30	+0·14	1	36	A
06·54	272·9	− 4·4	2·08	−0·08	2	15½	Comstock
07·56	273·0	− 1·2	2·30	+0·16	4	5	Scott
07·57	274·2	+ 0·1	2·09	−0·05	5	8	Tebbutt
07·62	270·6	− 3·4	1·78	−0·36	1	15½	Comstock
08·58	268·0	− 3·0	1·90	−0·22	1	15½	Comstock
09·86	270·0	+ 3·2	2·33	+0·25	4	8	Tebbutt
10·50	265·8	+ 1·1	1·96	−0·10	3	9	I
10·54	263·7	− 0·8	2·22	+0·16	3	12	Olivier
11·60	260·0	− 0·7	2·25	+0·23	4	8	Tebbutt
11·62	261·4	+ 0·6	2·16	+0·14	2	9	I
11·62	262·7	+ 1·9	1·96	−0·06	2	36	A
12·45	258·4	− 0·6	2·14	+0·16	2	9	I
12·57	257·6	+ 0·2	1·90	−0·07	2	36	A
13·56	254·8	+ 1·1	2·05	+0·13	4	9	I
13·58	251·6	− 2·0	1·77	−0·15	1	15½	Comstock
14·53	246·3	− 3·5	1·69	−0·19	1	15½	Comstock
14·57	249·8	+ 0·1	1·91	+0·03	4	9	I
14·60	249·4	− 0·2	2·10	+0·22	6	7	V
15·52	247·3	+ 1·6	1·80	−0·04	4	7	V
15·60	238·7	− 6·7	1·59	−0·24	1	15½	Comstock
15·62	245·6	+ 0·3	2·13	+0·30	2	9	I

Date	θ_0	O − C	ρ_0	O − C	n	Aperture (ins.)	Observer
	°	°	″	″			
1916·55	242·3	+ 1·1	1·82	+0·04	5	7	V
16·57	242·2	+ 1·1	1·90	+0·12	2	9	I
17·55	233·6	− 3·0	1·45	−0·29	2	15½	Comstock
17·58	236·2	− 0·3	1·79	+0·06	6	7	V
17·62	237·4	+ 1·1	1·90	+0·17	2	9	I
18·62	230·9	− 0·4	1·75	+0·08	2	9	I
19·70	227·0	+ 1·3	1·87	+0·24	4	17	δ
20·60	220·0	− 0·7	1·70	+0·11	2	9	I
20·88	220·0	+ 1·1	1·85	+0·28	4	17	δ
23·59	209·2	+ 6·9	1·67	+0·20	4	17	δ
24·39	197·2	+ 0·3	1·47	+0·02	6	7	V
25·33	188·2	− 2·1	1·52	+0·10	5	7	V
26·40	180·5	− 1·9	1·44	+0·06	5	7	V
26·48	181·0	− 0·8	1·55	+0·18	4	26½, 9	B
27·40	173·2	− 1·6	1·38	+0·03	4	7	Br
27·41	172·7	− 2·0	1·43	+0·08	5	7	V
27·50	174·2	+ 0·2	1·51	+0·17	4	26½	B
28·53	165·5	− 0·1	1·40	+0·10	4	26½	B
28·61	163·9	− 1·0	1·28	−0·02	3	7	V
28·71	164·5	+ 0·4	1·31	+0·02	4	26½	B
29·43	158·1	+ 0·4	1·23	−0·02	5	23½	V
29·50	157·4	+ 0·3	1·25	+0·01	4	26½	B
29·64	156·7	+ 0·9	1·28	+0·05		18	Costa
29·81	154·6	+ 0·4	1·32	+0·10	7	7, 14½	Wallenquist
30·23	150·3	+ 0·3	1·16	−0·03	5	23½	V
30·45	147·8	+ 0·1	1·18	+0·01	6	26½	B
30·66	145·5	0·0	1·13	−0·01	5	23½	V
30·68	146·6	+ 1·3	1·11	−0·03	2	26½	φ
31·17	140·2	+ 0·4	0·93	−0·14	4	23½	V
31·54	134·8	0·0	1·02	0·00	6	26½	B
31·58	134·5	+ 0·3	0·98	−0·03	6	26½	φ
31·62	133·8	+ 0·2	0·95	−0·05	3	23½	V
32·19	123·9	− 0·9	0·95	+0·06	3	26½	B
32·23	125·4	+ 1·4	0·82	−0·06	4	23½	V
32·42	121·9	+ 1·6	1·01	+0·17	1	17	δ
32·62	115·6	− 0·5	0·79	−0·01	6	23½	V
32·64	116·5	+ 0·9	0·80	0·00	5	26½	B
32·66	116·4	+ 1·2	0·76	−0·03	6, 5	26½	φ
33·22	97·7	− 1·6	0·71	+0·06	5	23½	V
33·27	99·1	+ 1·3	0·70	+0·07	2	26½	B
33·50	91·8	+ 2·9	0·68	+0·10	2	17	δ
33·55	85·0	− 1·8	0·58	0·00	4	26½	B
33·62	84·0	+ 0·4	0·47	−0·09	6	23½	V
33·64	82·8	+ 0·1	0·53	−0·03	8	26½	φ
33·66	80·0	− 1·8	0·53	−0·02	4	26½	B
34·21	54·6	+ 3·0	0·40	−0·09	3	23½	V
34·32	47·2	+ 2·2	0·49	0·00	3	23½	V
34·38	43·1	+ 1·6	0·55	+0·05	3	23½	V
34·51	35·5	+ 1·5	0·57	+0·07	3	23½	V
34·60	29·2	+ 0·3	0·60	+0·09	5	23½	V
34·62	28·2	+ 0·5	0·48	−0·03	8	26½	B
34·65	26·0	0·0	0·52	+0·01	8	26½	φ
35·23	1·4	0·0	0·63	−0·01	5	23½	V
35·25	0·1	− 0·6	0·67	+0·02	1	26½	B
35·26	1·1	+ 0·7	0·86	+0·20	1	17	δ

Date	θ_0	O − C	ρ_0	O − C	n	Aperture (ins.)	Observer
	°	°	″	″			
1935·60	350·8	+ 0·9	0·78	+0·02	8	26½	φ
35·63	349·0	− 0·2	0·76	−0·01	6	23½	V
36·25	337·9	+ 0·3	0·82	−0·12	4	23½	V
36·27	336·8	− 0·4	0·98	+0·03	4	15	Simonow
36·53	332·9	− 0·5	1·02	−0·01	8	26½	B
36·63	331·8	− 0·3	1·06	0·00	10	26½	φ
37·24	325·9	+ 0·6	1·16	−0·05	4	23½	V
37·26	325·1	0·0	1·14	−0·08	4	15	Simonow
37·42	323·2	− 0·4	1·27	+0·01	6	26½	B
37·60	323·9	+ 1·9	1·19	−0·11	1	26½	Tannenbaum
37·64	322·0	+ 0·3	1·26	−0·04	2	26½	φ
38·25	318·1	+ 1·0	1·38	−0·06	4	23½	V
38·54	315·3	+ 0·1	1·50	0·00	8	26½	B
38·64	314·1	− 0·4	1·50	−0·03	2	26½	φ
39·21	312·8	+ 1·6	1·57	−0·05	4	23½	V
39·57	308·9	− 0·4	1·57	−0·10	4	15	Simonow
39·63	309·4	+ 0·4	1·68	0·00	9	26½	B
40·56	304·9	+ 0·3	1·74	−0·06	4	26½	B
41·52	300·1	− 0·6	1·96	+0·05	5, 4	7	Hirst
41·65	301·1	+ 1·0	1·86	−0·06	4	26½	B
42·56	297·1	+ 0·3	1·94	−0·06	6	7, 26½	Hirst

The ephemeris up to 1960 is as follows:—

Date	θ	ρ	Date	θ	ρ	Date	θ	ρ
	°	″		°	″		°	″
1943·5	293·6	2·06	1949·5	274·7	2·14	1955·5	254·3	1·93
44·5	290·2	2·10	50·5	271·5	2·12	56·5	250·4	1·89
45·5	287·0	2·14	51·5	268·3	2·10	57·5	246·2	1·84
46·5	283·9	2·16	52·5	265·0	2·06	58·5	241·9	1·79
47·5	280·8	2·16	53·5	261·6	2·03	59·5	237·3	1·74
48·5	277·8	2·16	54·5	258·0	1·98	60·5	232·4	1·69

The corrections to all the elements, except the semi-axis major, were based on the angles only. The reason why the distances were not used is that the earlier ones, particularly those by northern observers, occasionally show large residuals which appear, as far as certain observers are concerned, to be systematic. Comstock, for example, invariably makes the distances much smaller than the general run while Tebbutt usually makes them larger.

The angle residuals are fairly satisfactory on the whole, though there are one or two runs of residuals of the same sign, notably that between 1934·21 and 1934·62 (all by Voûte) which has a curiously systematic appearance. None of these can be removed by adjusting the elements, however, without producing other similar runs in other parts of the orbit and it seems probable that they are all adventitious.

The long run of positive distance residuals from 1917·58 to 1928·53 is probably due mainly to low altitude or small aperture, as it seems impossible to remove them without spoiling the run of the angle residuals or else introducing a run of negative distance residuals elsewhere.

The earlier measures were obtained from published catalogues. The later ones were taken, by courtesy of the Union Astronomer, from the card catalogue at the Union Observatory, Johannesburg.

STELLAR PARALLAXES DETERMINED PHOTOGRAPHICALLY AT THE CAPE OBSERVATORY (FOURTEENTH LIST)

(Communicated by H.M. Astronomer)

(Received 1943 December 6)

This list is in the same form as previous lists.

It will be seen that the great majority of the stars lie in the zone $-40°$ to $-52°$. For these stars proper motion, generally exceeding $0''.2$ annually, had been determined from plates taken with the Astrographic Telescope. Some M-type stars with smaller proper motion were included, but no noteworthy parallaxes have been found. A few years ago a number of B-type stars with a spectroscopic parallax greater than $0''.01$ were put on the observing list and the first two trigonometric parallaxes have been determined. The proper motions given in the first line for each star have, for the zone $-40°$ to $-52°$, generally been taken from our astrographic work even when the star is contained in the G.C.

The observations for the most part extend over 9 or more epochs of large parallax factor. The probable error of observation appears to be larger the greater the number of epochs observed. This indicates the existence of a certain amount of systematic error at an epoch and the probable errors are probably nearer the true probable errors than those derived from 5 epochs only.

No.	Name and D.M. No.	Mag. Vis. Phot.	Type	R.A., Dec. (1900·0)	Unit $0''.001$ Proper Motion R.A.	Proper Motion Dec.	P.E. Unit Weight	Parallax	P.E.
				h m s					
1201	C.P.D. $-52°$ 12254	...	...	0 00 43	+ 270	+ 150	±26	+ 23	± 8
	Co.D. $-53°$ 9493	10·9		$-52°$ 51′·4	+ 210				± 4
1202	P.G.C. 72	6·90	Go	0 19 48	+ 533	− 260	±23	+ 27	± 6
	45 G Phœ	7·5		$-51°$ 35′·5	+ 530				± 3
1203	P.G.C. 78	2·44	Ko	0 21 21	+ 192	− 401	±30	+ 30	± 8
	α Phœ	3·44		$-42°$ 50′·9	+ 176				± 5
1204	G.C. 930	7·70	G5	0 41 35	+ 6	− 249	±30	+ 25	± 8
	$-5°$ 124	8·48		$-4°$ 58′·0	+ 28				± 5
1205	F.S. 331	...	K2	1 06 53	− 76	− 354	±31	+ 14	± 8
	$-44°$ 334	11·6		$-43°$ 58′·2	− 87				± 5
1206	F.S. 419	...	K7	1 26 53	− 362	− 208	±35	+ 25	± 9
	$-49°$ 424	11·6		$-49°$ 22′·9	− 360				± 5
1207	$-30°$ 529	7·19	G5	1 30 23	+ 159	+ 89	+31	+111	± 8
		8·0		$-30°$ 25′·5	+ 140				± 5
1208	Alb. 398	9·7	G5	1 34 17	+ 317	− 7	±27	+ 30	± 8
	$-27°$ 555	10·0		$-27°$ 45′·6	+ 247				± 4
1209	F.S. 503	...	...	1 44 57	− 396	+ 144	±27	− 6	± 8
	$-50°$ 502	12·4		$-50°$ 21′·3	+ 429				± 4

No.	Name and D.M. No.	Mag. Vis. Phot.	Type	R.A., Dec. (1900·0)	Unit 0″·001 Proper Motion R.A.	Proper Motion Dec.	P.E. Unit Weight	Parallax	P.E.
				h m s					
1210	F.S. 546	...	K5	1 56 46	+ 328	+ 62	±31	+ 16	± 8
	−46° 592	11·7		−46° 19′·6	+ 286				± 5
223	G.C. 2610	6·28	G5	2 06 24	+2159	+ 668	±28	+ 81	± 6
	−51° 532	7·3		−51° 18′·8	+2155				± 4
1211	P.G.C. 503	8·7	Go	2 07 40	+ 376	− 56	±32	+ 9	±10
	66^1 Ceti	...		−2° 51′·8	+ 340				± 8
1212	P.G.C. 504	5·72	Go	2 07 41	+ 369	− 63	±28	+ 17	± 9
	66^2 Ceti	6·28		−2° 51′·7	+ 361				± 7
	Mean	...	...	...	+ 373	− 60	...	+ 13	± 7
					+ 351				± 5
1213	F.S. 587	10·1	K2	2 10 36	+ 228	− 55	±34	+ 24	±10
	−50° 638	11·0		−50° 19′·6	+ 223				± 8
1214	F.S. 629	...	...	2 21 27	+ 262	− 142	±30	+ 21	± 9
	−42° 816	13·1		−42° 28′·5	+ 264				± 7
1215	F.S. 648	...	F5	2 27 12	+ 232	+ 89	±26	+ 6	± 8
	−51° 599	11·1		−51° 13′·5	+ 250				± 6
1216	F.S. 666	...	Ko	2 30 46	− 132	− 188	±31	+ 9	± 8
	−42° 862	10·5		−42° 36′·3	− 144				± 6
1217	F.S. 725	...	...	2 41 35	+ 169	− 226	±24	+ 28	± 7
	−41° 783	10·9		−41° 22′·6	+ 160				± 5
1218	F.S. 726	...	F8	2 41 37	− 149	− 137	±24	+ 20	± 6
	−42° 917	10·2		−41° 58′·9	− 162				± 5
1219	F.S. 759	...	...	2 48 32	+ 298	+ 98	±32	− 24	± 8
	−50° 847	11·7		−50° 49′·5	+ 289				± 7
1220	F.S. 858	...	Ko	3 05 33	+ 237	− 31	±24	− 12	± 7
	−49° 871	10·8		−49° 39′·9	+ 214				± 5
1221	F.S. 859	...	...	3 06 01	+ 240	− 35	±31	+ 5	± 8
	−44° 1003	11·6		−44° 07′·5	+ 205				± 7
1222	P.G.C. 722	5·14	F8	3 07 40	+ 195	− 59	±34	+ 10	±10
	94 Ceti	5·64		−1° 34′·2	+ 200				± 5
1223	−5° 598	8·80	G5	3 08 54	...	...	±33	+ 17	±11
		9·58		−4° 53′·2	+ 188				± 7
1224	F.S. 919	...	...	3 14 55	+ 335	− 79	±25	+ 20	± 8
	−50° 988	12·3		−50° 34′·7	+ 302				± 5
1225	F.S. 939	...	...	3 18 18	− 25	+ 304	±30	+ 22	±10
	−46° 1012	12·2		−46° 39′·7	− 30				± 3
1226	G.C. 4043	6·28	Go	3 18 25	+ 10	− 218	±26	+ 37	± 6
	A 2507	6·84		−8° 08′·6	+ 11				± 4
1227	−5° 762	8·20	Go	3 45 43	...	...	±33	+ 2	± 9
		8·76		−4° 55′·1	+ 15				± 6

No.	Name and D.M. No.	Mag. Vis. Phot.	Type	R.A., Dec. (1900·0)	Unit 0″·001 Proper Motion R.A.	Proper Motion Dec.	P.E. Unit Weight	Parallax	P.E.
				h m s					
1228	F.S. 1136	...	Ko	3 53 37	+ 72	+ 203	±29	+ 15	± 9
	−45° 1339	10·8		−45° 47′·7	+ 81				± 6
1229	−53° 630	9·1	G5	3 53 48	+ 250	+ 230	±32	+ 28	± 8
	H.D. 25061	10·3		−53° 13′·5	+ 233				± 6
1230	F.S. 1210	...	K5	4 05 57	+ 146	− 93	±34	+ 7	±10
	−51° 1022	10·8		−51° 50′·0	+ 142				± 6
1231	P.G.C. 995	4·36	F5	4 13 24	+ 100	+ 186	±28	+ 37	± 8
	γ Dora	4·78		−51° 44′·3	+ 73				± 5
1232	F.S. 1291	...	...	4 20 05	+ 190	+ 75	±36	+ 7	±10
	−44° 1536	12·5		−44° 41′·5	+ 185				± 6
1233	F.S. 1298	...	Ko	4 21 15	+ 114	+ 264	±25	+ 23	± 6
	47° 1364	10·7		−47° 24′·0	+ 107				± 4
1234	F.S. 1339	...	K	4 27 24	+ 154	+ 93	±33	+ 12	± 9
	−44° 1590	11·2		−44° 13′·1	+ 107				± 6
1235	F.S. 1383	...	...	4 33 30	+ 112	+ 178	±34	+ 30	± 9
	−46° 1466	11·8		−46° 41′·5	+ 116				± 6
1236	F.S. 1384	...	K7	4 33 39	+ 143	+ 10	±28	+ 18	± 8
	−42° 1571	11·3		−42° 52′·0	+ 147				± 6
332	Z.C. 2360	9·1	F8	4 35 09	+ 233	+ 179	±26	+ 24	± 6
	−40° 1499	9·5		−40° 23′·2	+ 226				± 1
1237	F.S. 1465	...	Ko	4 46 28	+ 106	+ 111	±30	+ 20	± 8
	−44° 1726	11·3		−44° 02′·1	+ 115				± 7
1238	Hyd. Astr.	...	*m*	5 04 07	+ 510	−1390	±38	+ 88	±11
	−18° 9743	12·1		−18° 15′·8	+ 496				± 7
	L.P.M. 205								
1239	P.G.C. 1262	3·68	B5	5 12 45	− 15	− 5	±33	+ 11	± 9
	τ Orio	3·56		−6° 57′·1	− 23				± 6
1240	P.G.C. 1401	2·75	B5*p*	5 36 02	− 1	− 26	±30	− 2	± 8
	α Colm	2·63		−34° 07′·6	− 2				± 5
1241	F.S. 2340	...	Ko	6 34 26	− 138	+ 165	±29	+ 2	± 8
	−43° 2572	10·6		−43° 34′·7	− 142				± 6
1242	F.S. 2361	...	Ko	6 36 17	+ 41	+ 210	±26	− 10	± 8
	−51° 2016	11·1		−51° 58′·2	+ 51				± 5
1243	Z.C. 3849	8·6	G5	6 40 56	− 88	+ 220	±26	+ 11	± 7
	−42° 2700	8·9		−42° 37′·1	− 91				± 5
1244	F.S. 2487	...	K2	6 47 07	+ 51	− 170	±27	+ 3	± 7
	−44° 2948	10·6		−44° 23′·7	+ 57				± 6
614	Ci 20, 399	6·77	K2	6 47 26	− 552	− 20	±24	+123	± 6
	−5° 1844	7·84		−5° 03′·2	− 548				± 1
1245	P.G.C. 1866	5·81	Go	7 09 34	+ 4	+ 97	±26	+ 18	± 6
	γ^1 Voln	6·37		−70° 20′·1	+ 12				± 4

No.	Name and D.M. No.	Mag. Vis. Phot.	Type	R.A., Dec. (1900·0)	Unit 0″·001 Proper Motion R.A.	Proper Motion Dec.	P.E. Unit Weight	Parallax	P.E.
				h m s					
1246	P.G.C. 1867	3·87	Ko	7 09 36	+ 20	+ 103	±30	+ 12	± 8
	γ^2 Voln	4·87		−70° 20′·2	+ 16				± 5
	Mean	...	...	...	+ 12	+ 100	...	+ 15	± 5
					+ 14				± 3
1247	G.C. 9994	6·86	G5	7 24 56	− 283	− 19	±31	+ 54	± 9
	−51° 2507	7·6		−51° 11′·9	− 270				± 5
1248	P.G.C. 1989	5·86	F2	7 30 05	− 94	− 1	±35	+ 16	±11
	A 6190	(6·4)		−23° 15′·3	− 80				± 5
	P.G.C. 1990	6·01	F2	7 30 06	− 110	− 13	±33	+ 23	±10
		(6·6)		−23° 15′·4	− 78				± 5
	Mean	...	...	...	− 102	− 7	...	+ 20	± 8
					− 79				± 4
1249	G.C. 10308	8·5	F8	7 36 17	− 20	− 207	±26	+ 18	± 8
	−50° 2899	8·2		−50° 50′·9	+ 6				± 4
1250	Z.C. 5035	7·5	Go	7 51 56	− 109	+ 180	±27	+ 11	± 7
	−41° 3536	8·1		−41° 34′·3	− 102				± 4
1251	G.C. 11173	8·10	Go	8 08 46	− 146	+ 113	±30	+ 24	± 8
	−40° 3959	8·6		−40° 12′·4	− 152				± 6
1252	Z.C. 7422	8·8	F8	9 25 01	+ 87	− 140	±30	+ 13	± 8
	−43° 5319	8·1		−43° 22′·2	+ 88				± 5
1253	F.S. 6906	9·4	Ko	9 52 06	− 140	− 70	±28	+ 65	± 9
	−40° 5628	10·0		−40° 18′·6	− 135				± 4
1254	F.S. 7466	...	...	10 09 43	− 197	+ 20	±32	+ 30	± 9
	−46° 5931	11·8		−46° 34′·0	− 191				± 6
1255	Z.C. 8507	...	G5	10 18 42	− 127	+ 80	±23	+ 23	± 6
	−45° 6014	9·7		−45° 58′·9	− 110				± 5
1256	F.S. 7987	...	...	10 30 40	− 121	+ 42	±33	− 8	±10
	−46° 6240	11·8		−46° 28′·7	− 117				± 7
1257	F.S. 8137	...	K	10 37 29	− 150	+ 44	±29	+ 26	± 9
	−41° 6052	12·6		−41° 43′·6	− 152				± 5
1258	Σ 3070 B	...	...	11 19 25	...	...	±34	+ 21	±10
	−3° 3109			−3° 50′·0	− 10				± 6
	Σ 3070 A	(9·6)	G5	11 19 26	...	...	±37	+ 5	±11
		(10·4)		−3° 50′·1	+ 2				± 7
	Mean	...	...	...	...	...	...	+ 13	± 8
					− 4				± 5
1259	F.S. 9012	...	F8	11 23 56	+ 157	− 41	±28	+ 10	± 7
	−50° 6041	10·5		−50° 15′·2	+ 169				± 6
1260	G.C. 16061	9·44	Ko	11 36 55	− 300	− 51	±30	+ 6	± 8
	−39° 7258	10·1		−40° 01′·0	− 299				± 6

No.	Name and D.M. No.	Mag. Vis. Phot.	Type	R.A., Dec. (1900·0)	Unit 0″·001 Proper Motion R.A.	Proper Motion Dec.	P.E. Unit Weight	Parallax	P.E.
				h m s					
1261	F.S. 9309	9·6	Ko	11 40 14	− 154	+ 19	±20	+ 13	± 5
	−40° 6927	10·1		−40° 11′·5	− 160				± 4
1262	Z.C. 9890	...	G5	11 46 26	+ 109	− 112	±24	+ 25	± 7
	−40° 6989	9·8		−40° 54′·6	+ 101				± 5
1263	F.S. 9589	...	G5	11 58 24	− 188	− 46	±25	− 6	± 7
	−48° 7090	11·3		−48° 37′·2	− 179				± 5
1264	Z.C. 10400	9·4	Go	12 22 08	− 330	− 214	±32	+ 10	± 9
	−47° 7625	9·7		−47° 34′·3	− 300				± 6
1265	G.C. 17435	8·73	Map	12 45 36	− 42	− 397	±30	+ 78	± 8
	+0° 2989	10·08		−0° 12′·8	− 25				± 6
1266	Z.C. 10811	...	G5	12 50 22	− 205	− 75	±30	+ 2	± 8
	−45° 8111	10·0		−45° 34′·7	− 160				± 7
1267	Z.C. 10991	8·3	Ko	13 00 48	− 319	− 133	±18	+ 34	± 5
	−49° 7643	9·2		−49° 08′·9	− 310				± 3
1268	F.S. 10914	...	G5	13 15 33	− 309	− 49	±30	+ 8	± 8
	−44° 8587	12·0		−44° 55′·6	− 320				± 5
1269	F.S. 11145	...	Mo	13 27 56	+ 43	− 52	±25	− 12	± 7
	−46° 8723	12·3		−46° 45′·0	+ 37				± 6
1270	F.S. 11170	...	Go	13 29 43	− 247	− 39	±20	+ 1	± 5
	−48° 8321	11·3		−48° 54′·1	− 237				± 4
1271	G.C. 18631	8·8	G5	13 41 33	− 192	+ 35	±26	+ 28	± 6
	−45° 8701	9·0		−45° 33′·9	− 197				± 5
1272	F.S. 11535	...	Ko	13 49 11	− 155	− 38	±37	+ 33	±10
	−44° 8976	10·4		−44° 37′·3	− 128				± 9
1273	F.S. 11607	...	G5	13 52 28	+ 134	− 68	±35	+ 20	± 9
	−49° 8351	10·9		−49° 18′·9	+ 159				± 6
1274	G.C. 20001	8·28	G5	14 46 23	− 79	− 177	±27	+ 25	± 7
	−46° 9649	8·9		−46° 13′·3	− 73				± 5
1275	F.S. 12679	...	Mo	14 56 21	− 293	− 8	±26	+ 56	± 7
	−45° 9610	11·3		−45° 54′·0	− 293				± 4
1276	F.S. 13112	...	Go	15 18 28	− 75	− 202	±28	+ 17	± 7
	−46° 10046	11·4		−46° 17′·0	− 78				± 5
1277	G.C. 21183	8·17	G5	15 39 53	− 125	− 149	±26	+ 12	± 6
	−42° 10755	8·4		−42° 55′·2	− 113				± 5
1278	Z.C. 14297	9·9	G5	15 54 52	− 157	− 119	±28	+ 6	± 6
	−44° 10569	9·6		−44° 09′·0	− 141				± 4
1279	Z.C. 14477	8·7	Go	16 06 38	+ 7	− 446	±22	+ 15	± 5
	−50° 10252	8·4		−50° 31′·0	+ 8				± 4
1280	F.S. 15369	...	G5	16 36 49	− 153	− 116	±27	+ 19	± 6
	−46° 10970	11·2		−46° 39′·9	− 151				± 5

No.	Name and D.M. No.	Mag. Vis. Phot.	Type	R.A., Dec. (1900·0)	Unit 0″·001 Proper Motion R.A.	Proper Motion Dec.	P.E. Unit Weight	Parallax	P.E.
				h m s					
1281	F.S. 15581	...	K2	16 43 40	− 6	− 409	±31	+ 33	± 8
	−43° 11160	10·9		−43° 36′·1	+ 7				± 7
1282	G.C. 23005	7·52	Go	16 57 21	+ 92	− 157	±30	+ 17	± 7
	−43° 11380	7·4		−43° 09′·8	+ 90				± 7
1283	Z.C. 15807	8·0	Ko	17 01 06	− 217	− 324	±34	+ 51	± 7
	−41° 11285	8·9		−41° 34′·9	− 208				± 6
1284	F.S. 18239	...	G5	18 37 26	− 116	− 284	±22	+ 28	± 5
	−51° 11742	11·1		−51° 31′·4	− 106				± 4
1285	F.S. 18384	...	...	18 50 46	+ 99	− 159	±29	+ 16	± 7
	C.A.Z. −48° 281	13·1		−47° 28′·3	+ 94				± 5
1286	Z.C. 17981	9·3	Go	19 02 21	− 48	− 475	±26	+ 6	± 6
	−48° 12933	10·0		−48° 37′·9	− 13				± 5
1287	L.P.M. 696	...	K	19 03 38	+ 170	− 460	±29	± 46	± 8
	Ross 727	13·4		−14° 53′·7	+ 150				± 5
1288	Z.C. 18369	8·5	G5	19 37 51	− 82	− 263	±23	+ 6	± 5
	−51° 12222	9·0		−51° 06′·0	− 75				± 4
1289	L.P.M. 761	...	*m*	20 56 41	− 220	− 470	±34	+ 70	± 8
	Wolf 906	12·0		−6° 42′·0	− 229				± 3
1290	P.G.C. 5445	5·84	F5	21 05 48	+ 43	− 221	±33	+ 39	± 7
	55 G. Micr	6·26		−40° 40′·3	+ 61				± 6
1291	F.S. 19464	...	G5	21 13 54	+ 192	− 138	±26	+ 41	± 6
	−51° 12903	11·3		−51° 27′·8	+ 194				± 4
1292	F.S. 19475	...	Ko	21 15 10	+ 196	− 107	±24	+ 25	± 6
	−51° 12912	10·8		−51° 46′·6	+ 179				± 4
1293	F.S. 19591	9·8	Ko	21 34 34	+ 40	− 181	±19	+ 35	± 5
	−43° 14655	10·9		−43° 46′·1	+ 44				± 3
1294	F.S. 19882	...	Mo	22 15 44	+ 52	− 123	±28	+ 18	± 7
	−47° 14163	12·2		−47° 30′·2	+ 50				± 5
1295	L.P.M. 842	....	K	22 48 26	−1040	−1000	±25	+111	± 7
	Ci 20, 1389	12·6		−75° 57′·5	−1066				± 5
1296	G.C. 31952	6·66	F5	22 49 26	− 226	+ 69	±30	+ 18	± 8
	−49° 13997	7·5		−49° 01′·6	− 208				± 6
1297	G.C. 31953	6·98	Go	22 49 27	− 222	+ 75	±23	+ 2	± 7
	−49° 13996	7·0		−49° 00′·0	− 237				± 5
1298	Z.C. 20470	9·3	F8	23 19 18	+ 93	− 222	±40	+ 18	±10
	−41° 15245	9·5		−40° 57′·8	+ 69				± 7
1299	Z.C. 20559	9·2	Go	23 29 28	+ 235	− 67	±31	+ 22	± 8
	−49° 14186	9·7		−49° 10′·9	+ 263				± 6
1300	G.C. 33182	8·4	G5	23 50 23	+ 178	− 70	±29	+ 13	± 8
	C.P.D. −52° 12227	9·0		−51° 55′·7	+ 127				± 6

Erratum

M.N., **103**, No. 5, Svein Rosseland, George Darwin Lecture:
Page 235, line 4, *for* $\bar{\rho}$ *read* ρ.

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‡Astronomische Abhandlungen:

Ergänzungshefte zu den Astronomischen Nachrichten. Band 10, Nr. 2 und Nr. 3. 4to. Berlin-Dahlem, 1940

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——: Kleinere Veröffentlichungen. Nr. 21, 22, 25. 8vo. Berlin, 1939–1941

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‡Breslau, Universitäts-Sternwarte:

——: Mitteilungen. Band V. 4to. Breslau, 1939
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British Association for the Advancement of Science:

Seismological Tables by Harold Jeffreys and K. E. Bullen. (*Gray Milne Trust.*) 8vo. London, 1940

‡Bruggencate (P. ten):

——: *Interstellare Linienabsorption. Cr. 8vo. Leipzig, 1940
——: *Sonnenprotuberanzen. 8vo. Potsdam, 1940
——: *Die Häufigkeit des Wasserstoffs in Sternatmosphären. 8vo. Leipzig, 1940

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——: *Bestimmung der Dämpfung zweier Fe-Multipletts für Mitte und Rand der Sonnenscheibe. 8vo. Berlin, 1940

†Brunt (David):

The Combination of Observations. Second Edition. 8vo. Cambridge, 1931

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†**Angelis (Stephanus de):**

Considerazioni sopra la forza di alcune ragioni fisico mattematiche . . . dal Riccioli . . . 4to. Venetia, 1667

‡**Astronomische Nachrichten:**

Band 273, Heft 1. Cr. 8vo. Berlin-Dahlem, 1924

‡**Astronomischer Jahresbericht:**

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‡**Berlin-Dahlem, Coppernicus-Institut (Astronomisches Rechen-Institut):**

Kleine Planeten, 1943. 8vo. Berlin, 1942

Berthoud (Ferdinand):

——: Traité des horloges marines . . . détermination des longitudes en mer. (*Mr. W. H. Owston.*) 4to. Paris, 1773

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†**Chiaramonti (Scipio):**

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†**Czynski (Jean):**

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†De Morgan (Augustus):

"Mathematical Biography extracted from The Gallery of Portraits By Augustus de Morgan, H.O.M.O.P.A.U.C.A.R.U.M.L.I.T.E.R.A.R.U.M."

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‡Guthnick (Paul):

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*Wiederauftreten des kurzperiodischen Lichtwechsels von γ Bootis. Cr. 8vo. Kiel, 1940

‡Houtgast (Jacob):

Variations in the profiles of strong Fraunhofer Lines along a radius of the solar disc.
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‡Innsbruck, Universitäts-Sternwarte:

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No. 13. H. Fischer, Farbmessungen an Kleinen Planeten.

†Kepler (Joannes):

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‡Leiden, Astronomical Institutes of the Netherlands:

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——: The Air Almanac, May–August 1943. 8vo. London, 1942
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*Table of the zeros of the Legendre polynomials of order 1–16 and the weight coefficients for Gauss' mechanical quadrature formula. 8vo. New York, 1942

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*On the function $H(m, a, x) = \exp(-ix)F(m+1-ia, 2m+2; ix)$. 8vo. s.l., 1942

‡—— **and Milton Abramowitz:**

*Table of integrals $\int_0^x J_0(t)dt$ and $\int_0^x Y_0(t)dt$. 8vo. s.l., 1943

†Ludlam (W.):

An introduction and notes on Mr. Bird's method of dividing astronomical instruments.
4to. London, 1786

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*Rational Electrodynamics. 8vo. London, 1943

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‡Wissenschaftliche Forschungsberichte:

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†Woodbury (David O.):

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Banerji (A. C.):

Recent Advances in Galactic Dynamics (Lucknow University Studies, No. XV). Sm. 8vo. Lucknow, 1942

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†*Observations d'une nouvelle Comète faites à l'Observatoire de l'Académie Royale des Sciences. 4to. Paris, 1672

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——: Discorso della cometa pogonare dell' anno MDCXVIII. (*Mr. W. H. Owston.*) 4to. Venetia, 1619

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Six articles in one volume by Burckhard, Habrecht, Lungwitius, Crueger (2), Basileus de Deutschenberg. (*Mr. W. H. Owston.*) 4to. v.l.

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——: §Nuevas Formulas para abreviar el calculo de la profundidad aproximada del foco sismico por el método de Köresligethy, y su aplicación a algunos temblores de tierra. 8vo. Madrid, 1921

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*A famous sunspot and its epilogue. 8vo. London, 1943

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